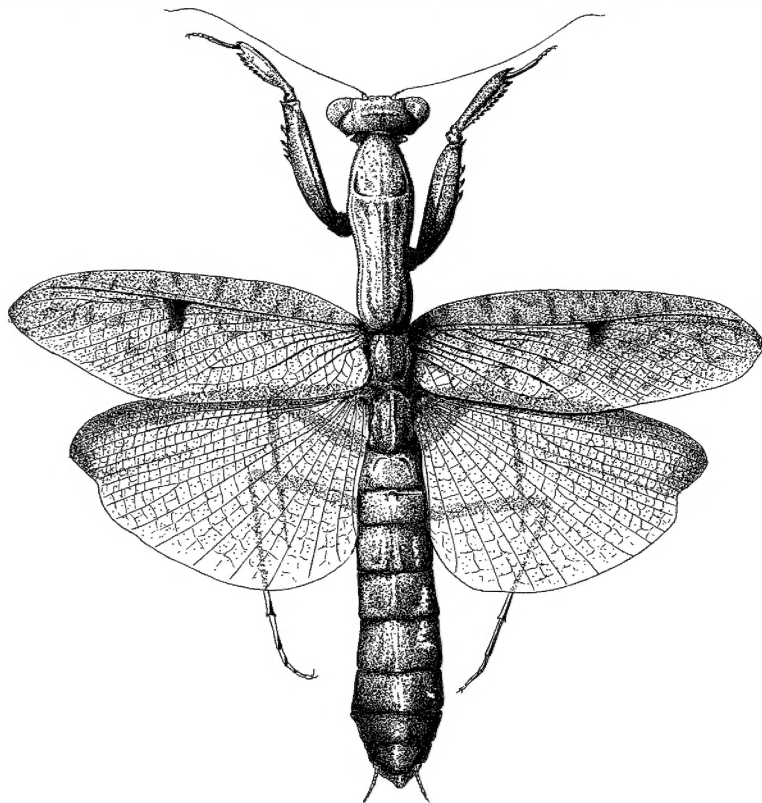


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COVER

This common eastern Australian mantid, *Sphodropoda tristis*, was described in 1871 by Henri Louis Frédéric de Saussure, an early Swiss worker on orthopteroids and wasps. Its Latin species name means 'sad'. Adults reach 63 mm and are greyish brown with fine patterning. When ready to deposit her ootheca, the female excavates a hole in soft soil with her strong, toothed forelegs. She backs into the hole, deposits the ootheca, then refills it using mid and hind legs. This was first observed by Brisbane school teacher, Roly Chapman, in 1981 and was published in this journal in 1984 (Vol 11: 5–7). Illustration is pen/ink stippling on paper by 2020 ESQ President, Mark Schutze, who is in charge of the DAF insect collection at Ecosciences Precinct in Brisbane. More of his work can be seen at exoskeletonprints.com/prints.html

NOTES ON THE DISTRIBUTION, HABITAT, BEHAVIOUR AND FLIGHT TIMES OF THE LARGE BRONZE AZURE, *OGYRIS IDMO* (HEWITSON, 1862) (LEPIDOPTERA: LYCAENIDAE), A RARE MYRMECOPHILOUS BUTTERFLY FROM SOUTH-WESTERN WESTERN AUSTRALIA

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Abstract

New locality records are given for *Ogyris idmo* (Hewitson, 1862), extending the butterfly's known distribution in Western Australia. The species is now known to occur in the northern Murchison district, in parts of the wheatbelt, and at additional sites in the south-west. Violet-purple female *O. idmo* butterflies have been found at intermediate inland sites between the purple western sub-populations and the iridescent blue south-eastern sub-populations. *Ogyris idmo*'s distribution closely matches that of its host ant *Camponotus terebrans* (Lowne, 1865). The butterfly's varied habitats, biology, unusual behaviour and flight times are reviewed and discussed. The conservation status of *Ogyris idmo* and future research priorities are identified.

Keywords: bi-voltine, colour-form, Pogonoscopini, ecology, management.

Introduction

The large bronze azure, *Ogyris idmo* (Hewitson, 1862) is an endemic Western Australian butterfly with an extensive though disjunct distribution: along the south-west coast around Perth; along a section of the south coast around Denmark to Cape Arid in the east, and in several inland areas including the jarrah forest east of Perth (Braby 2000). It is one of three known Western Australian butterflies whose larvae have progressed from phytophagy to a wholly myrmecophilous habit, where the butterfly larvae live within the ant nest and either prey on ants' brood (myrmecophagy) or are fed by the ants (trophyllaxis) (Field 1997, Eastwood and Fraser 1999; Pierce *et al.* 2002; Lundstrom and Williams *unpublished data*). The transition to this lifestyle dates back some 16 million years to the mid-Miocene (Schmidt *et al.* 2014) and as such, it belongs to a very select 'species group' within the genus *Ogyris* Angas, 1847.

Myrmecophilous butterflies are vulnerable to environmental perturbations due to their highly specialised trophic requirements. Several species are endangered in Europe (e.g. *Phenargis* Doherty, 1891 (*Maculinea* (Van Eeck, 1915)) spp.; Gimenez Dixon 1996a), in Africa (*Thestor*; Hübnér, [1819] IUCN 1996), and in Australia (*Ogyris* and *Acrodipsas* Sands, 1980; Braby and Douglas 2008, Schmidt *et al.* 2016, Gimenez Dixon 1996b, Breitfuss and Dale 2004, New and Britton 1997).

Conservation concerns for Australia's myrmecophilous *Ogyris* butterflies have long been raised; e.g. by D'Abrera (1971), Braby and Douglas (2008) and

Schmidt *et al.* (2016). The species within this group have all suffered severe range reductions as a result of widespread clearing for agriculture over the past 100 years. *Ogyris idmo* is the only species that still has a moderately wide distribution, with > 10 known sub-populations (Schmidt *et al.* 2016). Even so, its sub-populations are isolated and very local, and a number are now certainly extinct. Others are known only from single specimens, and whether or not these sub-populations persist is unknown. It is also unknown the extent to which sub-populations are ephemeral.

In Europe, understanding the complex life history and ecology of another myrmecophilous lycaenid butterfly *Phengaris (Maculinea) arion* (Linnaeus, 1758) was required before successful management strategies could be put in place to rescue that species from local extinction in England (Thomas *et al.* 2009).

Lack of basic biological information is a key limiting factor in the conservation of many at-risk butterflies. It is clear that greater knowledge of *O. idmo*'s overall distribution and the location of its widely dispersed sub-populations is required if the species is to be effectively managed. With this in mind, we have sought to (1) document all previously known sub-populations; (2) confirm the status of these sub-populations where possible; (3) and survey for new sub-populations. In addition, and where possible, we document the relative abundance of the *Camponotus terebrans* (Lowne, 1865) ant colonies which support the butterflies.

Methods

The following abbreviations refer to repositories where material has been examined:

DBCA:	Department of Biodiversity, Conservation and Attractions, Perth;
DPIRD:	Department of Primary Industries and Regional Development, Perth;
MCZbase:	Museum of Comparative Zoology, Harvard University Entomology Collection specimen database, Cambridge, Massachusetts;
NHM:	Natural History Museum, London;
PHC:	Private collection of Paul Hutchinson, Perth;
WAM:	Western Australian Museum, Perth.

The following abbreviations refer to collectors / observers listed in the tables:

AAEW Andrew Williams; AFA Andrew Atkins; AY Andy Young; CEM Cliff Meyer; CGM Grant Miller; DMK Daniel King; FH Fred Hort; HB Hugh Bollam; HL H. Loaring; HM H. Manskie; HMG H.M. Goerling; IFBC Ian Common; JH Jean Hort; KLD Kelvin Dunn; LJM L.J. Newman; MP Martin Purvis; MRW Matthew Williams; PMH Paul Hutchinson; PR Phyllis Robertson; PW Peter White; RAMC Rebecca Coppen; RPF Ross Field; RPM Peter McMillan; RPW Richard Weir; RWH Robert (Bob) Hay; SSB Steve Brown; SW Samantha Webb; TEL Trevor Lundstrom; TG Tim Gamblin; WL W. Loaring.

1. Published records / museum specimens: A search of the scientific literature and on-line insect databases (MCZbase) was undertaken to identify all published and unpublished *O. idmo* records. *Ogyris idmo* specimens in WAM, the DBCA

Lepidoptera reference collection, the DPIRD insect reference collection, and Paul Hutchinson's private collection (PHC), were examined for recent and historical locality information. An unusually labelled specimen in the NHM Lepidoptera collection was confirmed to be *O. idmo*.

2. Field surveys: Opportunistic searches for new *O. idmo* sub-populations were undertaken in conjunction with wide-ranging sun-moth surveys in Western Australia (Williams and Williams 2016; Williams *et al.* 2016), and surveys for graceful sun-moths *Synemon gratiosa* Westwood, 1877 between 2009 and 2019 (Williams *et al.* 2012; Williams *et al.* 2018a). In 2018 and 2019, targeted searches for *O. idmo* sub-populations were conducted in the transition zone between the south-western jarrah forest and open agricultural land where blocks of remnant forest and woodland are generally larger than in the central wheat-belt. Searches for the butterfly were also conducted north of Perth and in the wheatbelt, particularly at or near sites where *O. idmo* had been recorded historically.

Efforts were also made to locate additional *C. terebrans* ant colonies in the hope of finding new colonies of the butterfly. *Camponotus terebrans* occurs mainly in the cool temperate south-west, but also extends some distance into the more arid wheat-belt, where it may be narrowly sympatric with a closely related undescribed species, *Camponotus* sp. nr. *terebrans*, the host ant of *O. subterrestris petrina* (Field 1999).

Results

The *O. idmo* distribution map (Fig. 1) was compiled from previously known location data recorded in Dunn and Dunn (1991), Braby (2000), and from more recent records including: sites at Carramar and Koondoola Regional Bushland, on the Swan Coastal Plain near Perth (Williams and Williams 2006; Williams 2009); Tone Forest Block, about 40 km south-east of Manjimup (Williams and Williams 2006 incorrectly stated that this site was south-west of Manjimup); and Ledge Point, on the south coast near Albany (Williams and Williams 2006). Further north and inland, *O. idmo* has been recorded from 44 km north-east of Wubin (King and Williams 2014). The labels on previously overlooked *O. idmo* specimens in WAM's Lepidoptera collection provided valuable data on specimens collected between 1913 and 1923, a male collected east of Merredin in 1988, and an undated specimen from Wurarga, 170 km east of Geraldton (Table 1). In addition, we have specimen records from Mount Barker in DPIRD's Lepidoptera collection, from Pipidinnny Road near Yanchep and Melaleuca Park on the Swan Coastal Plain (PMH *pers. comm.* 2019; specimens are held in his private collection (PHC)). The data label on a specimen in the NHM, somewhat confusingly reads: **WESTERN AUSTRALIA: KALGOORLIE DISTRICT, W. SUBIACO, 23.x.1911, W.J. BROOKS**. It turns out that this specimen was not collected in Kalgoorlie, but at Shenton Park, a Perth suburb—Shenton Park was commonly known as 'West Subiaco' until the 1930's (Spillman 1985; City of Subiaco 2018). Field (1999) rightly discounted this specimen when he described *O. s. petrina*. Additional locality data were recorded from specimens recorded on the Harvard University MCZbase website (accessed 1/12/2019).

Table 1. *Ogyris idmo*—historical published records, institution database records, museum specimen records and private collection specimen records.

Locality	Latitude	Longitude	Habitat	Primary Reference
Wurarga, E Geraldton	28°25'00"S	116°17'00"E	Not recorded	HMG (WAM)
1 km S Port Denison	29°17'30"S	114°56'00"E	Dune swale, shrubs growing on exposed limestone pavement	Williams <i>et al.</i> 1995
44 km NE Wubin	29°49'47"S	116°57'23"E	Burnt roadside buffer zone with regenerating shrubs on gravel / sand	King and Williams 2014
16 km W Watheroo Town-site	30°19'04"S	115°53'37"E	Not recorded	Common and Waterhouse 1981
16 km E Merredin	31°29'00"S	118°17'00"E	Not recorded	RPM (WAM)
Cunderdin	31°29'00"S	117°14'00"E	Not recorded	Mrs Lundy (WAM)
Pipidinny Road, near Yanchep	31°34'58"S	115°40'08"E	Not recorded	PMH (PHC)
Melaleuca Conservation Park	31°40'42"S	115°53'37"E	Not recorded	PMH (PHC)
Perth, Carramar	31°42'19"S	115°48'07"E	Partially cleared grazed area adjacent to Banksia woodland	Williams and Williams 2006
Perth, Koondoola Regional Bushland	31°50'14"S	115°52'05"E	Banksia woodland on sand	Williams and Williams 2006 Williams 2009
Perth	Not recorded	Not recorded	Not recorded	Collector unknown (WAM)
Perth	Not recorded	Not recorded	Not recorded	HB RWH (MCZbase)
Perth, Shenton Park (W. Subiaco)	Not recorded	Not recorded	Not recorded	WJB (NHM)
Perth, Darling Range	Not recorded	Not recorded	Not recorded	HB RWH (MCZbase)
Perth, [Darling Range] Mundaring	Not recorded	Not recorded	Not recorded	LJ N (WAM)
Perth, [Darling Range] Mundaring [The Dell]	31°58'25"S	116°08'03"E	Jarrah forest	HB RWH (MCZbase)
Perth, [Darling Range] Martin	Not recorded	Not recorded	Not recorded	HB RWH (MCZbase)
Perth, [Darling Range] Bickley	Not recorded	Not recorded	Not recorded	HL WL (WAM)
Perth, [Darling Range] Pickering Brook	Not recorded	Not recorded	Jarrah forest	Williams & Williams 2006

Table 1 (cont.).

Perth [Darling Range] Bedfordale	Not recorded	Not recorded	Not recorded	HB RWH (MCZbase)
Perth, [Darling Range] Gleneagle[s] Forest	Not recorded	Not recorded	Not recorded	HB (WAM)
Jarrahdale	32°20'15"S	116°03'40"E	Not recorded	Mr Mangini (WAM)
North Bannister	32°05'03"S	116°27'00"E	Jarrah forest	Field 1990
Australind	33°17'00"S	115°43'00"E	Tuart forest	Atkins 1978
Bunbury	33°21'56"S	115°37'20"E	Vegetated near-coastal dunes	Atkins 1978
Balgownie, Manjimup	34°14'30"S	116°08'44"E	Not recorded	Collector unknown (WAM)
Tone Forest Block, 40 km SE Manjimup	34°23'45"S	116°29'15"E	Jarrah / Banksia woodland	Williams and Williams 2006
Stirling Range National Park	34°28'44"S	118°04'34"E	Mallee heathland	Field 1992, 1997
Mount Barker	34°39'21"S	117°38'51"E	Not recorded	LJN (DPIRD)
Windy Harbour, [Lighthouse Hill]	34°50'18"S	116°00'14"E	Not recorded	Field 1997
Wilson Inlet, near Denmark	Not recorded	Not recorded	Not recorded	Waterhouse and Lyell 1914
Ledge Point, near Albany	34°58'00"S	118°03'00"E	Winter-wet heathland	Williams and Williams 2006
10 km N Scaddan	33°20'30"S	121°42'55"E	Mallee / heath on sand	Braby 2000
Cape Arid National Park, Mount Ragged	33°27'52"S	123°27'35"E	Open mallee / heath	Field 1990

Two promising *C. terebrans* colonies were detected in the wheat-belt: one at Boodadong Nature Reserve, 10 km east of Wyening; and one east of Merredin (Williams *et al.* 2018b). Two other *C. terebrans* colonies were found further south: one near Tunney, south-east of Kojonup; and the other near Cranbrook, east-north-east of the Stirling Range, however, *O. idmo* butterflies were not detected at these sites.

New Records: Twenty eight new localities have now been recorded for *O. idmo* (Table 2). The two northernmost records are from the Murchison district along the North West Coastal Highway: one 40 km south of Billabong Roadhouse and the other at the Murchison River crossing. Further south a localised sub-population was recorded in Lesueur National Park, inland from Jurien Bay. *Ogyris idmo* sub-populations were also found at Wanagarran Nature Reserve, at Wilbinga, and at Neerabup National Park in Wanneroo. Additional sub-populations have also been recently located in forested areas inland and south of Perth. These

Table 2. *Ogyris idmo* - new records

Locality	Date	Habitat	GPS	Collector / Observer
Great Northern Highway, 40 km S Billabong Roadhouse	12.xi.2009	Mallee / shrubland on red-brown sand	27°10'28"S 114°36'59"E	AAEW (obs.)
Great Northern Highway, Murchison River Crossing	19.viii.1987	<i>Allocasuarina</i> riverine woodland, <i>Acacia</i> shrubland over grasses	27°49'35"S 114°41'21"E	AFA (obs.)
Lesueur National Park, Scenic Drive	19.x.2019	Banksia woodland over shrubs and sedges on whitish sand	30°10'09"S 115°11'51"E	AAEW
Wanagarra Nature Reserve	20.ii.2013	Shrubs and <i>Lomandra maritima</i> on dune ridge	30°46'23"S 115°12'25"E	RAMC
Bobtail Road, Wilbinga	11.ii.2010	Banksia and <i>Eucalyptus todiana</i> woodland over <i>Xanthorrhoea</i>	31°25'04"S 115°35'44"E	AAEW
Neerabup National Park, Wanneroo	7.ii.2011	Banksia woodland over shrubs on sand	31°38'08"S 115°43'10"E	TG AAEW
Wandoo National Park, Kent Road (N)	2.iii.2011	Very open jarrah over <i>Banksia attenuata</i> , low shrubs, white sand	31°57'49"S 116°30'48"E	AAEW
Wandoo National Park, Crawler Road	10.iii.2017	Wandoo and jarrah woodland over shrubs on lower slope	31°59'00"S 116°30'57"E	FH JH (Photo)
Wandoo National Park, Deefor Road	17.iii.2013	Open jarrah / wandoo woodland low shrubs / Patersonia on sand	31°59'24"S 116°31'17"E	FH JH (Photo)
Wandoo National Park, Catchment Road	2.xi.2013	Marri / jarrah open forest over <i>Banksia sessilis</i> shrub understory	32°02'26"S 116°35'37"E	FH JH (Photo)
Wandoo National Park, Kent Road (S)	13.iii.2013	Open jarrah / Wandoo / <i>Banksia</i> woodland over shrubs white sand	32°05'23"S 116°31'46"E	FH JH (Photo)
Perth, Darling Range, Mount Gungin	11.xi.2019	Low slashed vegetation along powerline track through jarrah forest	31°59'02"S 116°07'45"E	AAEW
Midgegooroo National Park, 20 km SE Armadale	28.xi.2009	Granite outcrop fringed with flowering shrubs	32°16'23"S 116°10'05"E	AAEW
Gordon Road, 17 km NE Dwellingup	6.xii.1994	Jarrah forest on sandy laterite soil	32°37'45"S 116°14'05"E	AAEW

Table 2 (cont.).

Wandering Conservation Park, 7 km N Crossman	11.xi.2018	Open marri / jarrah woodland over <i>Leptospermum erubescens</i>	32°42'24"S 116°34'18"E	AAEW
Powerline Track, 10 km E Waroona	13.xi.2019	Low slashed vegetation along powerline track through jarrah forest	32°50'16"S 116°01'57"E	AAEW
Nanga Road, 11.5 km E Waroona	10.xi.2011 13.xi.2019	Granite Rock fringed with flowering <i>Verticordia</i> shrubs / <i>Xanthorrhoea</i>	32°50'21"S 116°02'46"E	FH JH (Photo) AAEW
Williams Nature Reserve, 2 km NW Williams	29.x.2018	Open jarrah forest over <i>Banksia cardiaca</i> , low shrubs sedges	33°01'24"S 116°51'10"E	AAEW
Lavender Nature Reserve	6.xi.2019	Open jarrah woodland over burnt understory on laterite gravel soil	33°06'55"S 116°39'51"E	AAEW
Boscabel Bushland, 20 km NNW Kojonup	29.x.2018	Very open jarrah / <i>Banksia</i> wood land and shrubland on sand	33°39'52"S 117°05'43"E	AAEW
Stirling Range National Park	,xi.2012	Open <i>Eucalyptus wandoo</i> woodland over <i>Leptospermum</i> on white sand	34°19'08"S 118°11'36"E	AY
Stirling Range National Park	18.xi.2019	Mallee / shrubland on National Park boundary	34°22'00"S 117°41'09"E	AAEW
D'Entrecasteau National Park, Gardner River	9.xi.2017	Low open eucalypt woodland over dense sedges	34°46'41"S 116°10'43"E	AAEW
D'Entrecasteau National Park, Windy Harbour Road	23.xi.2017	Winter-wet swampland low shrubs and sedges	34°49'45"S 116°02'52"E	AAEW
2.5 km N Crystal Springs	17.xi.2010	Shrubs and sedges on slope near exposed granite sheet	34°57'19"S 116°36'16"E	AAEW
East Lake Bryde Nature Reserve	19.x.2017 5.xi.2019	Mallee and shrub-land on grey sandy clay soils	33°21'03"S 118°55'23"E	PW (Photo) AAEW
Lakelands Nature Reserve	6.x.2020	Mallee and shrub-land on grey sandy clay soils with laterite gravel	33°16'40"S 118°45'06"E	SW (Photo).
Cape Arid National Park, The Diamonds Hill	9.xi.2002	Mallee shrubland over heath and sedges on sand with laterite gravel	33°38'20"S 23°30'05"E	CEM SSB RPW



Fig. 1. Western Australia showing IBRA regions (Interim Biogeographic Regions of Australia) and all known records of *O. idmo*.

include a cluster of five sites in Wandoo National Park, one site on the Darling Range, and at four locations in the jarrah forest between Armadale and Waroona: Midgegooroo National Park; Gordon Road north-east of Dwellingup; and two sites east of Waroona. Along the Albany Highway, *O. idmo* sub-populations have been found in Wandering Conservation Park near Crossman, Williams Nature Reserve east of Williams, Lavender Nature Reserve 21 km south-west of Williams, and at Boscabel Bushland 20 km north-north-west of Kojonup. The remaining new *O. idmo* sites are located closer to the south-west and south coasts, namely Windy Harbour Road and Gardner River in D'Entrecasteaux National Park, Crystal Springs near Walpole, Lakelands Nature Reserve and East Lake Bryde Nature Reserve north-west of Lake Magenta, and The Diamonds Hill in Cape Arid National Park (CEM, SS Brown, RP Weir and CGM *pers. comm.*).

Distribution: *Ogyris idmo* is now known to occur from the semi-arid Murchison district east of Shark Bay to the temperate south coast near Walpole and Albany, a distance north to south of approximately 900 km (Fig. 1). The Wurarga, Wubin, Cunderdin and Merredin localities expand the species distribution 170 to 250 km inland from the west coast. Recent records from Wandering Conservation

Park, Williams Nature Reserve, Lavender Nature Reserve, Boscabel Bushland near Kojonup, Lakelands Nature Reserve and East Lake Bryde Nature Reserve are important because together with two records from near Manjimup (Balgownie and Tone Forest Block), and Mount Barker, they link the two discrete western and southern areas of occupancy mapped by Braby (2000). The East Lake Bryde site and nearby Lakelands Nature Reserve are particularly significant because they effectively bridge the gap between the south-western group of *O. idmo* localities and those to the east, at Scaddan and Mt Ragged in Cape Arid National Park. These eastern outliers originally appeared to be isolated and distinctive sub-populations, referred to as *O. idmo* ('Mt Ragged form') (Field 1999). In females from the semi-arid Mt Ragged site, the basal areas on the upper side of the wings is iridescent bright blue, rather than the characteristic purple of western and south coastal butterflies. Significantly, the upper side wing colour of females collected at East Lake Bryde Nature Reserve is violet to violet-purple, intermediate in colour between the western and eastern sub-populations. The wing colour of East Lake Bryde butterflies is not dissimilar to that of a female collected near Wubin, an inland northern site on the edge of the semi-arid zone (King and Williams 2014) and another female collected at Port Denison.

Interestingly, within the overall distribution, there appear to be four areas where clusters of *O. idmo* sub-populations occur. These sub-population groups are found in the jarrah forest on the Darling Range immediately east of Perth, in Wandoo National Park ~ 60 km inland from Perth, at D'Entrecasteaux National Park on the south-west coast, and at Cape Arid National Park, north-east and inland from Esperance.

Sub-population status: *Ogyris idmo* has been recorded at a total of 62 sites in south-western Western Australia (Table 3). The species is still present (or considered by us likely to be present) at 42 of these. At ten sites the sub-population status is unknown, and at the remaining ten localities the butterflies are now locally extinct. Of the 42 *O. idmo* sub-populations listed as 'extant' or 'presumed extant', only six can be regarded as having substantial or reasonably substantial numbers. These sub-populations are located at Williams Nature Reserve, mid-way between Perth and Albany, Boscabel Bushland north-north-west of Kojonup, the Crystal Springs site near Walpole, D'Entrecasteaux National Park on the south-west coast, East Lake Bryde Nature Reserve north of Lake Magenta, and Mount Ragged / The Diamonds Hill in Cape Arid National Park near Esperance.

Field (1997) reported that an intense fire in February 1991 destroyed all the above ground vegetation at Mount Ragged, but in October of the same year *O. idmo* was extremely abundant there. Interestingly the butterflies were quite rare again in October 1993 and October 1994. Some of our recent observations also suggest that the butterflies may be more numerous post-fire. For example, *O. idmo* was locally abundant at Williams Nature Reserve in October 2018, after a mild patch burn in the vicinity of a picnic site. The butterfly's appearance coincided with that of numerous flowering grass trees, *Xanthorrhoea preissii* Endl. (Asphodelaceae),

which flower very readily after fire. *Ogyris idmo* was also locally abundant north of Crystal Springs near Walpole in 2010, at a time when the vegetation was recovering after a fire the previous year. A similar situation prevailed at D'Entrecasteaux National Park in November 2017. However, at Boscabel Bushland and East Lake Bryde Nature Reserve, *O. idmo* butterflies were locally common without evidence of any recent fire.

At the other known *O. idmo* sites, the butterflies are generally uncommon, and in some places exist at exceptionally low densities. Examples include Koondoola Regional Bushland in Perth, where only a handful of adults have been observed, and none have been seen for >15 years, and Neerabup National Park in Wanneroo, where *O. idmo* adults were encountered on two occasions in February 2011. At Wanagarran Nature Reserve, Tone Forest Block near Manjimup, Ledge Point near Albany and Murchison River Crossing, only a single butterfly has ever been encountered. At the two northernmost sites (Murchison River Crossing and 40 km south of Billabong Roadhouse) the butterflies have been seen but not collected. The large Carramar sub-population on the Swan Coastal Plain is now extinct, as a result of urban development. Though very small, the *O. idmo* colony at Wilbinga is significant, being the only known viable bi-voltine sub-population (see below) in the vicinity of the Swan Coastal Plain. It has persisted there for at least nine years since it was first observed in February 2010. *Ogyris idmo* was locally common at a few sites on the Darling Range east of Perth in the 1970s, 80s and 90s (Field 1997), but butterfly numbers there appear to have declined in recent years (AAEW *pers. obs.* in 2018 and 2019). Field (1997) rated the conservation status of *O. idmo* at Darling Range as “rare” and at Cape Arid National Park as “rare (secure)”. Extant *O. idmo* sub-populations are now known to occur in six national parks, five nature reserves and one conservation park.

Habitat: *Ogyris idmo* occurs in a wide range of habitats. In the extreme north it is found in dry semi-arid shrubland growing on red sandy-clay soils overlain with fine granular pebbles. At Port Denison the butterflies occur among near-coastal dunes alongside *O. otaenes subhustis* (Williams and Hay 2001) in mixed *Melaleuca* L. (Myrtaceae) / *Acacia* Mill. (Fabaceae) / *Leptomeria* R. Br (Santalaceae) shrubland on exposed pavement limestone with peripheral banks of white sand. At Wanagarran Nature Reserve, adults are periodically encountered on vegetated coastal sand dunes, while round Perth, *O. idmo* sub-populations favour *Banksia* L.f. (Proteaceae) -dominated woodlands on the Swan Coastal Plain. Similarly, sub-populations in Wandoo National Park are generally found in pockets of habitat where there is a component of *Banksia* and jarrah (*Eucalyptus marginata* Donn ex Sm. (Myrtaceae) woodland on sand. Immediately east of Perth, *O. idmo* inhabits jarrah forest on the lateritic Darling Range. Further inland and south along the Albany Highway, at Williams Nature Reserve and Wandering Conservation Park, (Figs 2, 3), the butterflies are found in more open jarrah or marri (*Corymbia calophylla*) (Lindl.) K.D. Hill & L.A.S. Johnson (Myrtaceae) / jarrah woodland on laterite gravel uplands, with *Eucalyptus wandoo* Blakely (Myrtaceae) open woodland growing on the lower valley slopes. At D'Entrecasteaux National Park



Fig. 2. *Ogyris idmo* habitat at Williams Nature Reserve: open jarrah woodland over *Banksia squarrosa* shrubland.



Fig. 3. *Ogyris idmo* habitat at Wandering Conservation Park: open marri and jarrah woodland over *Leptospermum erubescens*.

Table 3. Status of *Ogyris idmo* sub-populations

Location	GPS	Sub-population status	Last observation	Source
40 km S Billabong Roadhouse	27°10'28"S 114°36'59"E	Presumed extant	12.xi.2009	AAEW
Murchison River Crossing, Great Northern Hwy	27°49'35"S 114°41'21"E	Presumed extant	19.viii.1987	AFA
Wurarga, E Geraldton	28°25'00"S 116°17'00"E	Unknown	Not recorded	(WAM)
1 km S Port Denison	29°17'30"S 114°56'00"E	Extant	9.xi.2018	MP
44 km NE Wubin	29°49'47"S 116°57'23"E	Extant	1.x.2012	AAEW
Lesueur National Park	30°10'09"S 115°11'51"E	Extant	19.x.2019	AAEW
16 km W Watheroo Town-site	30°19'04"S 115°53'37"E	Extinct	.xi.1958	IFBC
Wanagarran Nature Reserve	30°46'23"S 115°12'25"E	Extant	20.ii.2013	RAMC
Bobtail Road, Wilbinga	31°25'04"S 115°35'44"E	Extant	26.xi.2019	AAEW
16 km E Merredin	31°28'14"S 118°27'07"E	Unknown	9.x.1988	RPM (WAM)
Cunderdin	31°29'00"S 117°14'00"E	Extinct	1923	Mrs Lundy (WAM)
Pipidinnny Road, near Yanchep	31°34'58"S 115°40'08"E	Unknown	21.xii.2002	PMH
Neerabup National Park, Wanneroo	31°38'08"S 115°43'10"E	Extant	7.ii.2011	AAEW
Melaleuca Conservation Park	31°34'58"S 115°40'08"E	Unknown	16.xii.2004	PMH
Perth, Carramar	31°42'19"S 115°48'07"E	Extinct	22.ii.2003	AAEW
Perth, Koondoola Regional Bushland	31°50'14"S 115°52'05"E	Unknown	.iv.2002	PR
Wandoo National Park, Kent Road (N)	31°57'49"S 116°30'48"E	Extant	2.iii.2011	AAEW
Wandoo National Park, Crawler Road	31°59'00"S 116°30'57"E	Extant	10.iii.2017	FH JH
Wandoo National Park, Deefor Road	31°59'24"S 116°31'17"E	Extant	17.iii.2013	FH JH
Wandoo National Park, Catchment Road	32°02'26"S 116°35'37"E	Extant	2.xi.2013	FH JH
Wandoo National Park, Kent Road (S)	32°05'23"S 116°31'46"E	Extant	13.iii.2013	FH JH
Perth	Not recorded	Extinct	.i.1916	(WAM)
Perth	Not recorded	Unknown	26.xi.1988	HM

Table 3 (cont.).

Perth, Shenton Park (W. Subiaco)	Not recorded	Extinct	23.x.1911	WJB (NHM)
Perth, Darling Range	Not recorded	Presume extant	14.xi.1985	RWH
Perth, [Darling Range] Mundaring	Not recorded	Unknown	.xi.1913	LJN (WAM)
Perth, [Darling Range] Mundaring, [The Dell]	31°58'25"S 116°08'03"E	Extant	11.xi.2019	AAEW
Perth, [Darling Range] Martin	32°04'53"S 116°02'56"E	Presumed extant	18.xi.1990	HB
Perth, [Darling Range] Bickley	Not recorded	Extinct	1916	HL WL (WAM)
Perth, [Darling Range] Pickering Brook	Not recorded	Presumed extant	23.xi.1994	TEL
Perth, [Darling Range] Bedfordale	Not recorded	Presumed extant	23.xi.1990	RWH
Perth, [Darling Range] Gleneagle[s] Forest	Not recorded	Presumed extant	19.xi.1988	HB
Perth, Darling Range, Mount Gungin	31°58'48"S 116°07'07"E	Extant	16.xi.2020	AAEW
Midgegooroo National Park, 20 km SE Armadale	32°16'04"S 116°10'05"E	Presumed extant	28.xi.2009	AAEW
Jarrahdale	32°20'15"S 116°03'40"E	Unknown	Not recorded	(WAM)
North Bannister	32°05'03"S 116°27'00"E	Unknown	.xi.1989	RPF
Gordon Road, 17 km NE Dwellingup	32°37'45"S 116°14'05"E	Presumed extant	6.xii.1994	AAEW
Wandering Conservation Park	32°42'08"S 116°35'39"E	Extant	28.x.2019	AAEW
Powerline Track, 10 km E Waroona	32°50'16"S 116°01'57"E	Extant	13.xi.2019	AAEW
Nanga Road, 11.5 km E Waroona	32°50'21"S 116°02'46"E	Extant	13.xi.2019	AAEW
Williams Nature Reserve	33°01'24"S 116°51'10"E	Extant	30.x.2020	AAEW
Lavender Nature Reserve	33°06'55"S 116°39'51"E	Extant	6.xi.2019	AAEW
Boscabel Bushland, 20 km NNW Kojonup	33°39'52"S 117°05'43"E	Extant	30.x.2020	AAEW
Australind	33°17'00"S 115°43'00"E	Extinct	.x.1978	AFA
Bunbury	33°21'56"S 115°37'20"E	Extinct	.x.1978	AFA
Balgownie, Manjimup	34°14'30"S 116°08'44"E	Extinct	Not recorded	(WAM)

Table 3 (cont.). Status of *Ogyris idmo* sub-populations.

Location	GPS	Sub-population status	Last observation	Source
Tone Forest Block, 40 km SE Manjimup	34°23'45"S 116°29'15"E	Presumed extant	7 xi.2004	AAEW
Stirling Range National Park	Not recorded	Presumed extant	Not recorded	RWH (R.P. Field 1997)
Stirling Range National Park (E)	34°19'08"S 118°11'36"E	Extant	.xi.2012	AY
Stirling Range National Park (W)	34°22'00"S 117°41'09"E	Extant	18.xi.2019	AAEW
Mount Barker	34°39'21"S 117°38'51"E	Unknown	Not recorded	LJN (DPIRD)
D'Entrecasteau National Park, Gardner River	34°46'41"S 116°10'43"E	Extant	9.xi.2017	AAEW
D'Entrecasteau National Park, Windy Harbour Road	34°49'45"S 116°02'52"E	Extant	23.xi.2017	AAEW
Windy Harbour, Lighthouse Hill	Not recorded	Presumed extant	27.xi.1989	PMH
2.5 km N Crystal Springs	34°57'19"S 116°36'16"E	Extant	17.xi.2010	AAEW
Wilson Inlet, near Denmark	Not recorded	Extinct	Not recorded	Not recorded
Ledge Point, near Albany	34°58'00"S 118°03'00"E	Presumed extant	1.xii.1999	AAEW
Lakelands Nature Reserve	33°16'33"S 118°44'44"E	Extant	6.x.2020	SW
East Lake Bryde Nature Reserve	33°21'03"S 118°55'23"E	Extant	19.x.2019	AAEW
10 km N Scaddan	33°20'30"S 121°42'55"E	Presumed extant	3.xi.2010	AAEW
Cape Arid National Park, Mount Ragged	33°27'52"S 123°27'35"E	Extant	13.x.2014	CEM, CGM, SSB
Cape Arid National Park, The Diamonds Hill	33°38'20"S 123°30'05"E	Extant	11.x.2014	CEM, CGM, SSB

on the south-west coast, the butterflies are found in extensive low-lying sedge swampland. In this habitat the surface substrate is sand. Much of the area is inundated in winter, though islands of marginally higher ground remain dry. At Stirling Range National Park, Lakelands Nature Reserve, East Lake Bryde Nature Reserve and Cape Arid National Park the habitat is mallee shrubland / heathland over a substrate of generally grey sandy-clay with intervening areas of sand. As *O. idmo* occurs in such a wide range of habitats, it is clearly not habitat specific.

Life cycle and behaviour: Scant information is available on the life history of *O. idmo*. Published information in Braby (2000) has been taken primarily from

Trevor Lundstrom's observations of egg-laying behaviour at Pickering Brook in November 1994 (TEL and MRW *unpublished data*). We paraphrase a section of Lundstrom's field observations here:

*“In November 1994, T.E. Lundstrom witnessed egg-laying behaviour at Pickering Brook east of Perth. Over a few days he observed female *O. idmo* flying short distances, settling on the ground and then walking around under bushes and shrubs and in amongst the leaf-litter apparently in search of *Camponotus terebrans* ant nests. On one occasion a female located a small hole in the soil at the base of a jarrah sapling, and this proved to be the entrance to a *C. terebrans* nest. Having located the entrance, the butterfly backed into the entrance hole with its abdomen in an arched position and expressed an egg into the jaws of a waiting ant. The ant then carried the egg directly down into the galleries below.”* (Braby 2000, T.E. Lundstrom and M.R. Williams *unpublished data*).

We have observed similar behaviour in the open jarrah woodland at Williams Nature Reserve (Fig. 2). Females flew short distances before settling on the ground. They remained stationary for a period before walking cautiously over the soil and amongst leaf litter below *Banksia squarrosa* (R. Br.) A.R. Mast & K.R. Thiele (Proteaceae) understory shrubs, but we did not witness any egg-laying.

At East Lake Bryde Nature Reserve, Peter White (DBCA operations officer), observed a female *O. idmo* flying short distances, periodically settling on the ground, presumably in search of ant [scent] trails. The wing colour in flight was described as a distinctive bluish/purple hue (*email correspondence* P. White to M.R. Williams 25.x.2017 and 30.x.2017). The butterfly always settled with wings



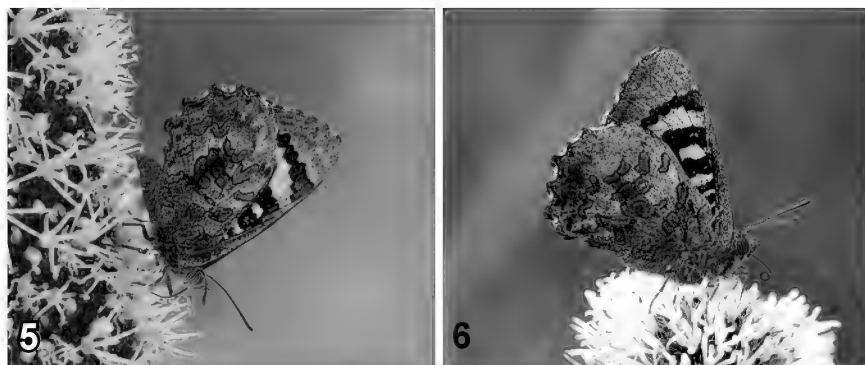
Fig. 4. Female *Ogyris idmo* on the ground near Crystal Springs. The alternating movement of the hind wings up and down obscures then reveals the pale cream spot on the underside of the forewing. Photo Andrew Williams (DBCA).

closed upright, often moving the hind wings alternately up and down, obscuring, then revealing the cream spot on the forewing rather like the opening and closing of a semaphore signal lamp. Identical behaviour was observed near Crystal Springs (Fig. 4) (AAEW *pers. obs.* .xi.2010). At Lakelands Nature Reserve, Samantha Webb (DBCA field officer), videoed female *O. idmo* hindwing behaviour on 6.x.2020. Whether this behaviour has any signalling significance is unknown. Tailed Lycaenidae are known to move their hindwings, presumably to focus the attention of a predator on the hindwing (false head) and thereby avoid being eaten. Although *O. idmo* has scalloped edges to its hindwings (rather than tails), and lacks eyespots its hindwing movements may still serve a semiotic function.

Adult *O. idmo* activity patterns vary between sites (see Atkins 1978, Field 1990, Braby 2000, Williams and Williams 2006). At Pickering Brook and Mundaring on the Darling Range, females are active in the mornings between 10 am and noon. After a midday lull, males start flying at 1 pm. Males patrol along tracks and only land if conditions are cool or overcast - typically, they fly continually. The few females collected after 1 pm have all been in perfect or almost perfect condition and we suspect that they were unmated (Williams and Williams 2006). Mated females are thought to roost in the treetops after noon, practicing 'male avoidance', as none were ever disturbed from the ground or low-level vegetation at these sites. Similarly, at Williams Nature Reserve, females (almost exclusively) are on the wing during the morning with males only appearing in numbers after midday. The exact opposite occurs at East Lake Bryde Nature Reserve where males are active in the mornings. After midday only females are active. On Perth's Swan Coastal Plain at Carramar (colony now extinct) males and females were seen between 9.30 am and 3 pm Western Standard Time (WST). Males were abundant and defended well-defined territories along a kilometre of sand track which bordered on *Banksia* woodland. They landed frequently on twigs or low vantage points. Females were seldom seen (Williams and Williams 2006).

Ogyris idmo males have been recorded flying up to three or four metres above the ground in Tuart forest near Australind (Atkins 1978). The only other record of this high-flying behaviour was at Wandering Conservation Park, in tall open marri and jarrah woodland (Fig. 3), where males flew at similar heights over a tall and widespread *Leptospermum erubescens* Schauer (Myrtaceae) understory.

Ogyris idmo visit flowers when available. In October 2018 both males and females were photographed on flower spikes of *Xanthorrhoea preissii* grass trees at Williams Nature Reserve, females in mid-morning and males around midday (Fig. 5). Similarly, at Pickering Brook both sexes have been observed feeding together in the early morning (7–8 am). On the south coast *O. idmo* adults obtain nectar from the flowers of *Dasypogon bromeliifolius* R. Br. (Dasypogonaceae) (Fig. 6). The species also visits the flowers of *Verticordia plumosa* (Desfontaines) Druce (Myrtaceae) round the perimeter of rocky outcrops in the jarrah forests east of Waroona (FH and JH *pers. comm.* 2019).



Figs 5, 6. *Ogyris idmo*. (5) Female on *Xanthorrhoea preissii* flower-spike; (6) male on *Dasypogon bromeliofolius*. Photos: Andrew Williams (DBCA).

Annual Flight times: The principal flight period for *O. idmo* is spring and early summer (Table 4). Braby (2000) lists *O. idmo* as flying from September to December. More recently, Williams and Williams (2006) documented two distinct flight periods for two sub-populations on the Swan Coastal Plain, at Carramar and Koondoola Regional Bushland. The first flight period is in late spring to early summer (from early November to mid-December), the second is in late summer to early autumn (February, March and April). These flight periods were consistent over time, being verified by one of us (AAEW), who monitored *O. idmo* butterflies at Carramar from October to April over three years. The butterflies were abundant at Carramar in November and December but absent in January. They reappeared in smaller numbers in February, March and April. Interestingly, *O. idmo* on the lateritic Darling Range immediately east of Perth, fly in spring and early summer but have never been recorded in autumn (Table 4). The Pickering Brook site was monitored throughout a season by one of us (MRW), who confirmed that this sub-population had a single (uni-voltine) flight period (Williams and Williams 2006).

Three new *O. idmo* sub-populations were located during DBCA's graceful sun-moth autumn surveys, at Wilbinga (February 2010), Neerabup National Park (February 2011), and Wanagarran Nature Reserve (February 2013). We recorded the butterflies again at Wilbinga in November 2018, February 2019 and November 2019, confirming that this small colony has persisted at the same site for at least nine years, and like those at Carramar and Koondoola Regional Bushland, it has a bi-voltine flight pattern. *Ogyris idmo* at the intermediate Neerabup National Park site almost certainly flies in spring, and this is likely to be true also for *O. idmo* in the undulating dune and swale landscape at Wanagarran Nature Reserve. In Wandoo National Park ~ 60 km east of Perth *O. idmo* also has a bi-voltine flight pattern (Table 4). The cluster of sub-populations in Wandoo National Park generally occur in pockets of *Banksia* and jarrah woodland on sand. Braby and Douglas (2008) consider this bi-voltine flight pattern in some sub-populations but not others to be biologically unusual and therefore deserving of closer

examination. The flight-time chart (Table 4) shows that October and November are the core activity months for *O. idmo* in spring and early summer (15 records in October and 29 in November), while February and March are the core activity months in late summer and early autumn for sub-populations which have a bi-voltine flight pattern. The only record for January is from Perth in 1916.

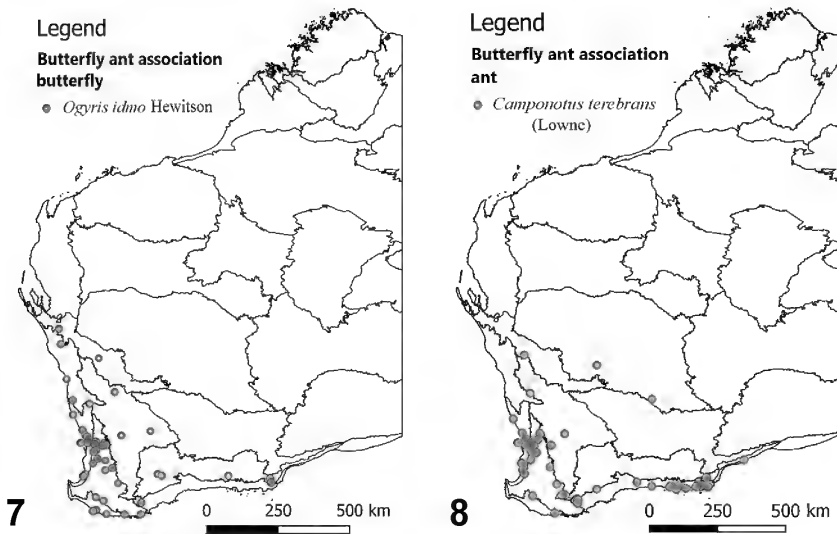
Discussion

The pattern of *O. idmo* known sub-populations (Fig. 1) suggests that *O. idmo* once had a more extensive if patchy distribution in Western Australia. The butterfly's inherent rarity was likely exacerbated by the loss of a substantial proportion (~50%) of its original habitat, when the central and southern wheat-belt region was cleared for agriculture. Label data on several old specimens in WAM's Lepidoptera reference collection confirm that the butterfly occurred there. The last known specimen from the wheat-belt was collected in 1988 from east of Merredin, in an area where relatively large blocks of uncleared land, including some nature reserves, still remain. *Camponotus terebrans* ant colonies have been found at a site east of Merredin (Williams *et al.* 2018b), but whether *O. idmo* butterflies occur there is yet to be determined.

The mapped location points for *O. idmo* can be compared with location points plotted for *C. terebrans* (Figs 7, 8): the distribution pattern for the butterfly and its host ant match reasonably well, which suggests that *O. idmo* specialises on this single host ant species. *Camponotus terebrans* occurs in a wide range of habitats (Heterick 2009). Field (1997) states that "although rare, *O. idmo* is widespread in south-western WA, and [like the ants] occurs in a variety of habitats".

In the jarrah forest, east of Perth, *O. idmo* is most often found along corridors of cleared native vegetation, typically 50m wide, which are maintained by the state government to protect high-voltage electrical transmission lines. Regular slashing and maintenance of these corridors results in regular soil disturbance, accumulation of small logs and other debris, and regular regrowth of young vegetation. Males patrol these cleared corridors, particularly along vehicle access tracks, where they tend to congregate near high points. As the butterflies are also found in naturally occurring openings within the forest, the use of these open powerline corridors may simply be opportunistic behaviour. *Camponotus terebrans* ants are known colonisers of disturbed sites (Field 1997, Adams *et al.* 1997) (BEH *pers. comm.* 2019), and the numerous colonies occurring along the corridors may also account for the butterfly's presence. Field (1997) noted that *O. idmo* in the Darling Range near Perth was found in places near where urban development, forestry and fire were disturbance factors.

Where *O. idmo* occurs in forest or woodland, the trees are frequently rough-barked *Eucalyptus* or *Banksia* species, growing over a mixed understory of shrubs and sedges. The host ant nests are often difficult to find, because the ants are nocturnal and remain underground during the day. Their nest entrances are small inconspicuous holes in the ground, and some at least may be sealed during the day



Figs 7, 8. Distribution of (7) *Ogyris idmo* and (8) host ant *Camponotus terebrans*.

to deter predatory meat ants *Iridomyrmex purpureus* (Smith, 1858) (R. Eastwood *pers. comm.* 2019). Some colonies occur beneath dead woody material, such as logs and tree stumps. Finding and estimating the size of these underground ant colonies, which support *O. idmo* butterflies, is often difficult. In March 2020, *C. terebrans* ant nests were found at Williams Nature Reserve, where *O. idmo* butterflies had been recorded in 2019 (Table 3). The ant nests were in laterite-derived loamy soil with very small laterite pebbles, in open jarrah woodland (Fig. 2). Excavated ant tunnels led to small ant galleries located under the protective root systems of shrubs or sedges. This observation establishes that *C. terebrans* ants are not always confined to sandy soils (McArthur *et al.* 1997).

Ogyris idmo butterflies are also found in smooth-barked *Eucalyptus wandoo* woodlands in the Stirling Range National Park (Andy Young *pers. comm.* 2019). In these woodlands, discrete *C. terebrans* ant nest entrance holes are found at the bases of *E. wandoo* trees. In March 2020, we observed the ants escorting leafhoppers *Pogonoscopus lenis* Jacobi, 1909 at night, from the subterranean ant nests and up the tree trunks to feed on sap through the trees' smooth bark (Fig. 9). The attendant ants then fed on the flow of liquid excretions from the feeding leafhoppers. In the semi-arid zone, pale-coloured *Camponotus* sp. nr. *terebrans* ants, which support a colony of the critically endangered *O. subterrestris petrina* butterflies, also shepherd *P. lenis* leafhoppers up smooth-barked eucalypts at night. This leafhopper was previously identified as *P. myrmex* China, 1924 (Gamblin *et al.* 2010, Williams *et al.* 2018b). However, re-examination and comparison of fresh material from the *O. s. petrina* colony and Stirling Range National Park, including

Table 4 (cont.): *Ogyris idmo*—monthly flight-time record. Orange coloured cells represent the spring brood and blue the autumn brood. The single January record, from Perth in 1916, has not been allocated to either brood.

Locality	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Williams Nature Reserve, 2 km NE of Williams			AAEW	AAEW					
Lavender Nature Reserve, 21 km WSW Williams				AAEW					
Boscabel Bushland, 20 km NNW Kojonup			AAEW	AAEW					
Australind			AFA						
Bunbury			AFA						
Tone Forest Block, 40 km SE of Manjimup					AAEW				
Stirling Range National Park (E)				AY					
Stirling Range National Park (W)				AAEW					
D'Entrecasteaux National Park, Gardner River				AAEW					
D'Entrecasteaux National Park, Windy Harbour Road				AAEW					
Windy Harbour, Lighthouse Hill				PMH, RWH					
2.5 km N Crystal Springs				AAEW					
Ledge Point, near Albany					AAEW				
Lakelands Nature Reserve			SW						
East Lake Bryde Nature Reserve			PW	AAEW					
10 km N Scaddan			KLD	AAEW					
Cape Arid National Park, Mount Ragged		RWH CEM <i>et al.</i>	CEM <i>et al.</i>						
Cape Arid National Park, The Diamonds Hill			CEM <i>et al.</i>	CEM <i>et al.</i>					

genitalia dissections of males from both sites, indicates that the leafhopper is *P. lenis* (Evans 1966) at both locations (Melinda Moir, DPIRD, South Perth pers. comm. .iii.2020). Treehoppers in the tribe Pogonoscopini are adapted to living in ants' nests (Day and Pullen 1999). It is interesting that a single pogonoscopine leafhopper is found in the nests of two closely-related *Camponotus* Mayr, 1861 ants, which also host two closely-related myrmecophilous *Ogyris* butterflies.

Field (1997) reported that *O. idmo* adults were extremely abundant at Mount Ragged in Cape Arid National Park in October 1991, after an intense wildfire in the previous summer had burnt all the above ground vegetation. We speculate that the fire had either an impact on *C. terebrans* foraging or on the *O. idmo* larvae inside their nests. As a result, it appears that large numbers of *O. idmo* larvae reached maturity simultaneously, with the resultant mass emergence of butterflies in October 1991. Further study of *O. idmo* colonies following fire should be encouraged to determine if this is the case, as it may have implications for their conservation. The length of time that *O. idmo* larvae take to develop to adulthood inside a *C. terebrans* ant nest is unknown.

The six *O. idmo* sub-populations found in isolated blocks of remnant native vegetation along the western edge of the wheat-belt, south-south-east of Perth, suggest that the butterflies and their host ants have persisted in these isolated patches since the surrounding land was cleared for farming in the early to mid 1900s. These blocks vary considerably in size; Lakelands Nature Reserve (3,200 ha), Wandering Conservation Park (2,380 ha), East Lake Bryde Nature Reserve (1,500 ha), Lavender Nature Reserve (287 ha), Williams Nature Reserve (200 ha) and Boscabel Bushland (108 ha). The distance between these isolated blocks and the main southern jarrah forest varies from 6 km (Wandering Conservation Park) to 50 km (Boscabel Bushland). The *O. idmo* sub-populations at Lakelands and East Lake Bryde nature reserves are 10 km north of the extensive mallee woodlands on Lake Magenta Nature Reserve. Although *O. idmo* is a powerful flyer, it may be difficult for the butterflies to traverse such distances over open farmland with few patches of intervening native vegetation. Thus, natural recolonization from outside may be unlikely. Indeed, Schmidt *et al.* (2014) note that “*Ogyris idmo* species-group taxa have probably always been patchily distributed with widely separated sub-populations so that recolonization of locally extinct colonies would become increasingly unlikely as populations become isolated by habitat fragmentation (New 2011)”.

The *O. idmo* sub-populations in now isolated patches of the original southern jarrah forest, at Wandering Conservation Park, Lavender Nature Reserve, Williams Nature Reserve and Boscabel Bushland, have increasing conservation value given that much of the southern jarrah forest block between Boddington and Hoffman's Mill (all potential *O. idmo* habitat) is now impacted by rapidly expanding bauxite mining operations (see recent Google Earth satellite imagery).



Fig. 9. *Camponotus terebrans* ants with *Pogonoscopus lenis*, Stirling Range National Park. Photo: Eleanor Williams.

Conclusion

Ogyris idmo has an extensive, but patchy distribution in both temperate and semi-arid parts of south-western Western Australia. It has now been recorded from 62 localities, though only 42 of these are still extant or presumed extant (Table 3). The butterfly has been recorded from seven national parks, five nature reserves and one conservation park. From a conservation standpoint *O. idmo* is better conserved than the other Australian myrmecophilous *Ogyris* butterflies: *O. subterrestris subterrestris* (Field, 1999), *O. s. petrina* (Field, 1999), and *O. halmaturia* (Tepper, 1890), which are all now identified as endangered or critically endangered (Braby and Douglas 2008, Braby *et al.* 2011, Schmidt *et al.* 2014). With its extraordinary myrmecophilous lifestyle and exceptionally ancient lineage, *O. idmo* surely deserves the greatest possible protection from State and Federal conservation agencies.

We identify the following future research priorities to assist conservation of this rare and elusive butterfly.

- 1 Investigation is needed to determine the details of the life history of *O. idmo* in order to better understand the factors which influence the butterfly / host ant relationship. Only when this is well understood will land managers be

able to make informed decisions on how to best conserve the butterfly and its host ant colonies.

- 2 Locating additional *O. idmo* sub-populations in conservation estate would help to confirm the security of the species. The initial focus of surveys should be in the north, where fewer extant sub-populations are known. Surveys in the south, between Albany and Esperance, should focus on Lake Magenta Nature Reserve, Fitzgerald River National Park, and the bushland areas to the west, south and north-east of Ravensthorpe.
- 3 Studies at Stirling Range National Park may be useful to document any *O. idmo* response to the extensive 2019–2020 summer wildfires.
- 4 Targeted surveys for *O. idmo* in the wheat-belt should be undertaken at Tank Hill Nature Reserve and nearby remnant woodlands east of Merredin, where *O. idmo* was last recorded in October 1988.

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COVIDTHRIPS NOVENDECIM, AN ISOLATED NEW PHLAEOTHIRIPINE TAXON (THYSANOPTERA) FROM QUEENSLAND

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Abstract

A new genus and species of Thysanoptera, Tubulifera *Covidthrips novendecim* **gen. n., sp. n.** is described that was collected from rain forest canopy in southeast Queensland. This Australian endemic is presumably fungus-feeding, and the unusually broad maxillary stylets suggest a possible relationship to the Phlaeothripinae, Docessissophothripini.

Keywords: Phlaeothripidae, Docessissophothripini, rainforest canopy, new genus

Introduction

Studies on Australian biodiversity were severely constrained for much of 2020. Widespread forest fires, followed by restrictions on travelling and crossing state borders in order to contain the disease known as COVID-19, severely limited field work. As a result, biodiversity studies turned inward, re-examining and re-organising data already available on computers. For Thysanoptera, this led to production of a web-based identification system for pest species that have the potential to invade Australia from adjoining countries (Watson and Mound 2020), also a related project on thrips that induce leaf galls on *Piper* vines in southeast Asia and northern Australia (Mound 2020a). The latter project stimulated a review of the literature on “gall thrips”, focussing on the lack of biological data behind that term, and particularly the behavioural diversity amongst thrips that occur in galls but do not induce these growths (Mound 2020b).

Apart from reduced field work, access to museum collections was also severely restricted due to COVID-19 precautions. As a memorial to this *annus horribilis* of severely reduced biodiversity studies the following new taxon is described here, with the genus and species names derived from Covid-19. Moreover, the phylogenetic isolation of this new genus suitably reflects the physical isolation of so many biologists. The two female specimens were collected over 30 years ago from the canopy of a rainforest tree using an insecticide fogging technique. Regrettably, this technique has not been deployed more extensively for thrips faunal studies, despite evidence that some Thysanoptera species are largely confined to the canopy and are rarely taken through more normal sampling methods. For example, Lima *et al.* (2020) refer to the remarkable species, *Arachisothrips millsii* Stannard (1952), as having been taken in large numbers only through canopy fogging in Costa Rica. Similarly, Palmer (1986) reported from southern England that *Drepanothrips reuteri* Uzel (1895) was taken in large numbers from the canopy of *Quercus robur* although this thrips is not found on the foliage of these trees at a collector’s head height. Also, Stork (1991) reported remarkably large numbers of Thysanoptera collected by a similar technique from the canopy of rainforest trees in Borneo.

Acknowledgements and abbreviations

I am grateful to Professor Shuji Okajima, Tokyo, for discussing the systematic relationships of this new genus. The only abbreviations used here are for the tergal and sternal setal pairs; those nearest the mid-line are designated S1, the pairs placed more laterally as S2 and S3.

Covidthrips gen. n.

Macropterous Phlaeothripinae with head almost twice as long as wide (Fig. 1), genae constricted behind eyes but with a pronounced tubercle, dorsal surface with extensive reticulation (Fig. 2); maxillary stylets 4–5 microns wide, retracted to compound eyes and close together medially. Antennae 8-segmented (Fig. 3), VIII clearly separate from VII, segment III with 3 sense cones, IV with 4. Fore tarsal tooth in female as long as tarsal width; fore tibia inner margin with small sub-apical tubercle (Fig. 4); fore femur swollen with stout papilliform tubercle medially (Fig. 1). Pronotum with 4 pairs of major setae, notopleural sutures complete; mesonotum with postero-median cleft (Fig. 5); metanotum reticulate. Prosternal basantra absent, ferna transverse, mesopresternum formed of 3 sclerites; metathoracic sterno-pleural sutures present. Fore wings broad, parallel-sided, with 14–20 duplicated cilia. Abdomen with pelta relatively small and triangular (Fig. 5); tergites II–VII each with 2 pairs of sigmoid wing-retaining setae and one pair of long, weakly capitate, marginal setae (Fig. 7); tergite IX setae S1 and S2 weakly capitate, S3 longer and acute (Fig. 6). Sternites with transverse row of fine discal setae, postero-marginal setae S1 and S2 arise sub-marginally, S3 small or absent. Male not known.

Type species *Covidthrips novendecim* sp. n., by monotypy.

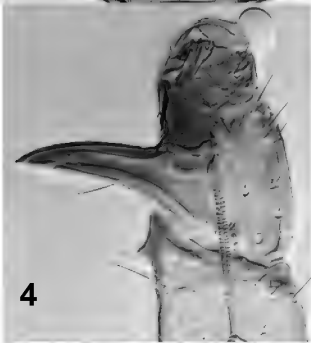
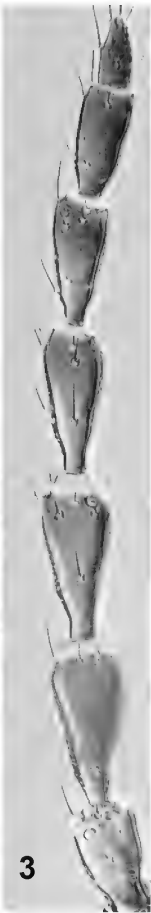
Relationships

The maxillary stylets are exceptionally long and unusually wide, indicating that this is not a phytophagous member of the Phlaeothripinae. The antennal sense cone formula of three on segment III and four on segment IV is shared with various fungus-feeding Phlaeothripinae in the genera *Hoplandrothrips* Hood (1912) and *Hoplothrips* Amyot and Serville (1843) (Mound and Tree 2013; Mound *et al.* 2020). But species in those genera are similar to phytophagous species in having maxillary stylets no more than three microns in diameter, in contrast to the broader stylets of this new species that are almost five microns in diameter. The width and length of these stylets suggest a relationship to *Holothrips* Karny (1911), a worldwide genus of fungus feeding species that was extensively reviewed by Okajima (1987), and of which 10 species are known from Australia (Mound and Tree 2014). *Holothrips* is considered a member of the Tribe Docessissophothripini, in which the species have unusually long maxillary stylets that are generally close together medially in the head. However, none of

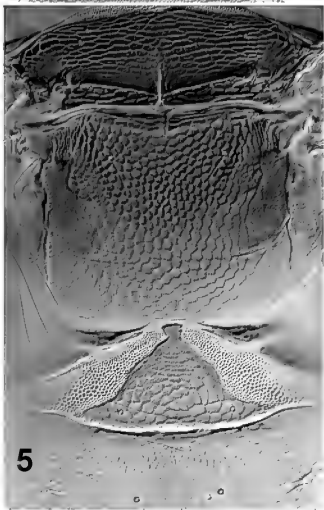
Figs 1–7. *Covidthrips novendecim* gen. and sp. n. female. (1) head, pronotum, fore legs and antenna; (2) head; (3) antenna; (4) fore tarsus and tibial apex; (5) mesnotum, metanotum and pelta; (6) tergites IX, X; (7) tergites III–IV.



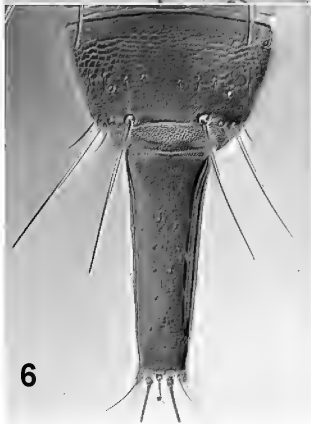
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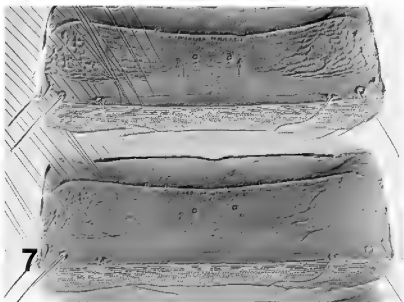
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the nine genera in that group (Mound and Palmer 1983) include species with a tubercle on the fore femora nor a small tubercle on the fore tibiae. Moreover, most of those species have antennal segments VII and VIII closely joined or even fused. Each of those nine genera has a restricted range in some part of the wet tropics around the world, and this new species is presumably an endemic in Australian rainforests.

***Covidthrips novendecim* sp. n.**

(Figs 1–7)

Female macroptera. With the character states of the genus indicated above. Bicoloured, head and thorax brown, abdomen brownish yellow with darker marking medially on tergites; tube reddish-yellow with apex darker; mid and hind tibiae, tarsi and femora yellow, also fore tibiae and tarsi; antennal segments I–III yellow, IV–VII increasingly dark on their apices; major setae pale, but anal setae dark brown; fore wings almost uniformly pale. Head with a cruciform area lacking sculpture medially and between the postocular setae (Fig. 2); compound eyes bulbous, smaller ventrally and with a stout apodeme that largely isolates a group of ommatidia postero-medially; postocular setae long and weakly capitate. Pronotum with weak reticulation on anterior third, am setae no larger than discal setae. Mesonotal lateral setae minute; metanotal median setae finely acute (Fig. 5). Abdominal tergites weakly reticulate medially, with tergal wing-retaining setae placed laterally; tergite IX setae S1 and S2 about four-fifths as long as tube.

Measurements (holotype in microns). Body length 3000. Head, length 350; maximum width across genae 200; postocular setae length 100. Pronotum, length 250; width 400; prothorax width across coxae 550; pronotal setae lengths: anteromarginals 25, anteroangulars 60, midlaterals 75, epimerals 410, posteroangulars 400. Fore wing length 1000; sub-basal setae 50, 70, 105. Tergite IX setae length, S1 170, S2 175. Tube length 250. Antennal segments III–VIII length 100, 95, 90, 75, 70, 45.

Material studied. Holotype female, **Australia**, Queensland, Mt Glorious State Forest, from *Argyrodendron actinophyllum* [Malvaceae], 19.iv.1987 (Yves Basset), in Australian National Insect Collection, CSIRO, Canberra.

Paratypes: one female taken with holotype.

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FIRST RECORDS OF THE EUROPEAN WOOL CARDER BEE, *ANTHIDIUM MANICATUM* (LINNAEUS, 1758) (HYMENOPTERA: MEGACHILIDAE: ANTHIDIINI) IN AUSTRALIA

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Abstract

The first records of the European wool carder bee, *Anthidium manicatum* (Linnaeus, 1758), in Gippsland, Victoria, Australia are reported. Reasons for the success of the bee family Megachilidae and success of the world's most widespread, unmanaged bee, *A. manicatum*, are discussed. The spread of *A. manicatum* in the USA and New Zealand and the spread of the recently introduced African carder bee, *Pseudoanthidium (Immanthidium) repetitum* (Schulz, 1906), in Australia are considered in relation to the potential spread of this new invasive bee in Australia. The only apparent limiting factor to the spread of *A. manicatum* appears to be the availability of the plant family Lamiaceae, from which it cards or scrapes plant-fibres used for nesting material. The effect of this bee on the Australian native bee fauna and its potential to proliferate sleeper weeds in Australia are examined in relation to overseas observations. Exotic status terminology, ranging from adventive to invasive, is provided for the seven non-native bee species now found in Australia.

Keywords: Invasive species, citizen science, human-modified transport

Introduction

Megachilidae is one of the largest bee families in the world with more than 4,000 species in over 80 genera (Ascher and Pickering 2020). The success of this family has been attributed to one key innovation, the inclusion of foreign material into unlined, brood cell nest construction. This habit has underpinned both the massive range expansion and a significant increase in the rate of diversification of Megachilidae (Litman *et al.* 2011). World-wide, cavity-nesting megachilid bees, especially *Anthidium* Fabricius, 1804 (Anthidiini) are among the most commonly adventive, solitary bee species (Gonzalez *et al.* 2010). *Anthidium* contains more than 160 species in six subgenera worldwide (Gonzalez and Griswold 2013, Litman *et al.* 2016) and they are conspicuous because of their black and yellow-striped abdomen and robust body form (Strange *et al.* 2011). *Anthidium* can be found on all continents, where bees occur, except in Australia (Niu *et al.* 2020). Their diversity and ability to invade new habitats, combined with the use of above ground nesting cavities, particularly human made or modified structures with pre-existing or easily excavated cavities such as wooden boxes and pallets, window frames, bricks or beetle burrows in wood (Michener 2007) or in hollow plant stems (Strange *et al.* 2011) may be linked to the Megachilidae use of foreign nest material. These nesting materials are easily moved by human activities or through the nursery plant trade to new regional, national or international locations (Cane 2003). *Anthidium* bees are called “wool carder bees”, as females engage in elaborate nest building behaviour that is suggestive of wool being ‘carded’ between spiked brushes before being spun (Donovan 2007). Females use their

mandibles to ‘card’ nesting material by scraping trichomes off leaves and stems, and rolling this into balls which are transported back to nesting cavities (Gonzalez and Griswold 2013, Soper and Beggs 2013, Wilson and Carril 2016).

The European wool carder bee, *Anthidium manicatum* (Linnaeus, 1758) (Anthidiini), is about the size of a honeybee and is perhaps the world’s most widespread, unmanaged bee (Strange *et al.* 2011). It is native to Europe, Asia, and North Africa but has spread to other regions including the United States of America (USA), Canada, New Zealand, Siberia, Canary Islands and South America (Gibbs and Sheffield 2009, Strange *et al.* 2011, Burrows *et al.* 2018). *Anthidium manicatum* was initially introduced unintentionally to north-eastern USA in 1963. The species spread slowly until 1996 when detections increased substantially, and the bee now occurs across the USA. Given the wide distribution and varied range of habitats this species now occupies, its spread does not appear to be limited by climate but rather by its nesting behaviour and foraging diet (Strange *et al.* 2011). The rapid continental spread appears to be a combination of Megachilidae nesting traits and its preference to nest in association with human urban areas. For brood cell construction, this species is restricted to using the plant family, Lamiaceae, from which it cards or scrapes plant fibres and its distribution may be limited by the presence of introduced European plant species (Strange *et al.* 2011). Females also collect glandular secretions from plants and apply these to the cell, perhaps to waterproof or prevent microbial growth inside the nest (Müller *et al.* 1996). Nests are constructed of a tangled mass of plant fibres in blind cavities in plant and other materials (Donovan 2007). The clypeus of *A. manicatum* is densely covered with modified apically hooked pollen-collecting hairs used for pollen collection from nototribic (bilabiate or dorsal pollen deposition) flowers of the plant families Lamiaceae, Fabaceae and Plantaginaceae (Gonzalez and Griswold 2013, Vitalea *et al.* 2017). The species is polylectic with floral visitation records in the USA on at least nine plant families including Acanthaceae, Asteraceae, Boraginaceae, Crassulaceae, Fabaceae, Lamiaceae, Lythraceae, Malvaceae and Plantaginaceae (Strange *et al.* 2011, Gonzalez and Griswold 2013). In France and Germany, the species has similar floral records with the addition of the plant family Scrophulariaceae (Wirtz *et al.* 1992). First discovered in New Zealand in 2006, *A. manicatum* was recorded visiting 15 plant families, of which 80% visited were exotic species of Lamiaceae and Plantaginaceae. By 2012, *A. manicatum* was recorded throughout much of New Zealand (Soper and Beggs 2013). The flight period for *A. manicatum* is between five to seven months over the summer months (Strange *et al.* 2011) and it may undergo two or three generations before overwintering as pre-pupae (Soper and Beggs 2013). In New Zealand, the predicted flight period was between December and April (Donovan 2007) which should be similar in Australia. *Anthidium manicatum* is restricted to human-modified habitats and nests in holes and cavities in wood or hollowed stems of plants, which can facilitate human assisted transport particularly from plant nursery stock (Strange *et al.* 2011).



Figs 1, 2. *Anthidium manicatum* male flying around *Plectranthus graveolens* R.Br. (bush basil) (Lamiaceae). Photos by MFS.

Most solitary bees exhibit a range of similar characteristics. Females are generally larger in body size than males and the sex ratio is male biased. Females of solitary bees mate only once or are receptive to mating for a short period which places selection pressure on males to find a receptive female first. To enhance male access to receptive females as soon as possible, males of solitary bees emerge before females emerge. However, *A. manicatum* does not fit this general pattern. Males are larger than females, the operational sex ratio has a strong female bias and the flight period for both sexes is similar (Wirtz *et al.* 1992); although the sex ratio can vary between years (Strange *et al.* 2011). Females mate repeatedly and throughout the flight season which allows *A. manicatum* males to act differently to other solitary male bees as there is not the selection pressure to be the first male to find a receptive female bee (Wirtz *et al.* 1992). Since *A. manicatum* males do not need to actively search for females, the larger males (male body length 12.3–17.7 mm) select a particular floral resource which they guard and become aggressively territorial around and will actively defend these preferred mating sites, often mating multiple times with the same female (Wirtz *et al.* 1992). They primarily attack conspecific males but will attack any bee that enters their territory, in particular *Apis mellifera* Linnaeus, 1758 and *Bombus* Latreille, 1802, using their robust metasomal spines (Fig. 7) to break or disable wings during aerial battles. *Anthidium manicatum* males sometimes continue these attacks with injured bees on the ground (Pechuman 1967, Gonzalez and Griswold 2013). *Anthidium manicatum* females obtain a significant advantage by having their floral resources defended by males. In consideration of the rapid colonisation of *A. manicatum*, its preference to nest in urban areas, its use of human-modified structures and human-aided transportation, its ability to adapt to different climates and habitats and its potential negative effects on native bees, it should be considered an invasive rather than an adventive species (Strange *et al.* 2011).

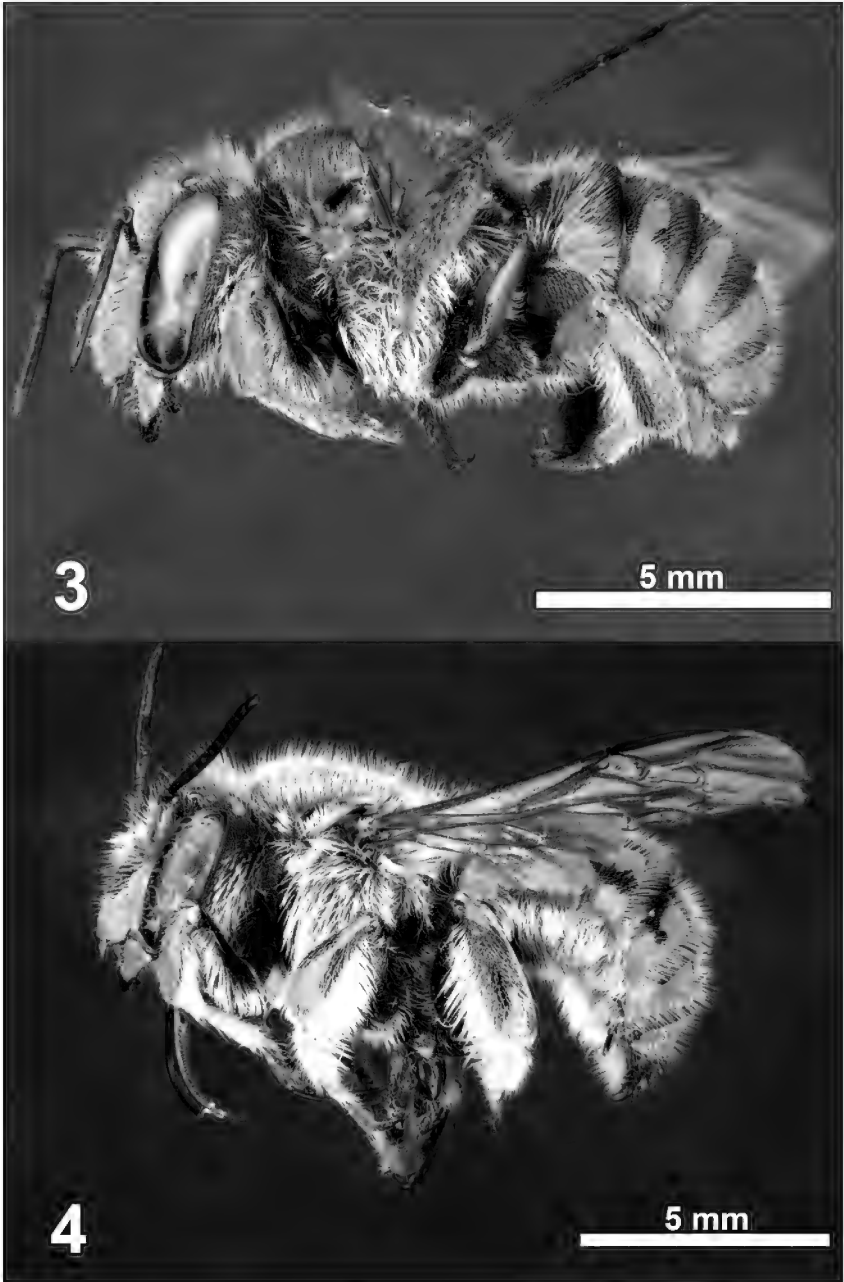
This paper reports the first Australian records of *A. manicatum* in Gippsland, Victoria. Its potential spread and impact on native flora and fauna are considered.

Detection and Abbreviations

Identification of web images and collected specimens was made by K LW with reference to literature resources (Gonzalez and Griswold 2013, Burrows *et al.* 2018). These two reports are currently the only known occurrences of *Anthidium* in Australia. The body size, colour markings of both sexes and carding behaviour of females and aggressive territorial behaviour of males are unlike any native Australian bee. The three collected specimens of *A. manicatum* were deposited in the entomology collection of Museums Victoria (two males HYM-91764 and HYM-91765; one female HYM-91766). Abbreviations: T1–T7 is for metasomal terga 1–7 and S8 is for metasomal sternum 8.

Results

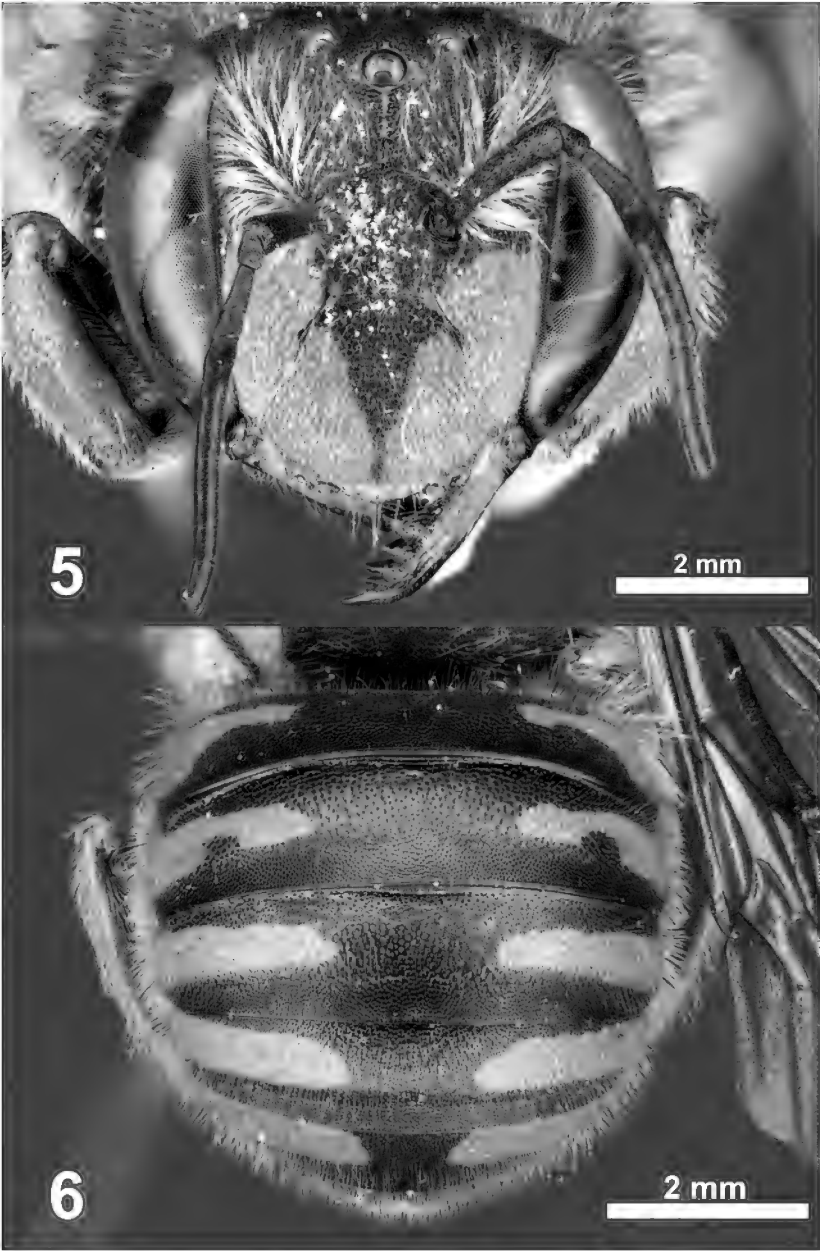
The first record of *A. manicatum* in Australia was through the BowerBird citizen science website. This website is no longer available but most records were transferred to iNaturalist (<https://www.inaturalist.org/projects/bowerbird>) [last



Figs 3, 4. *Anthidium manicatum* lateral views. (3) female; (4) male. Photos by KLW.

accessed 10 July 2020] and then uploaded to Atlas of Living Australia (ALA <https://www.ala.org.au/>) [last accessed 10 July 2020]. On 22 December 2018 at about 12:30 pm, MFS took a series of 10 images of a single male specimen of *A. manicatum* visiting flowers of an Australian native shrub *Plectranthus graveolens* R.Br. (Bush Basil) (Lamiaceae) and sitting on leaves (Figs 1, 2). The leaves of this plant are densely covered with spreading to retrorse hairs and densely covered with gland-tipped hairs (Plantnet FloraOnline 2020a). The male bee visited several plants in a small area for about 30 minutes before disappearing. MFS's images were first uploaded to BowerBird on 22 December 2018, then later transferred to iNaturalist <https://www.inaturalist.org/observations/26300675> [last accessed 10 July 2020] and uploaded to ALA in July 2019 (ALA <https://biocache.ala.org.au/occurrences/037f6b39-58c8-488b-bb5a-e63607361bc1>) [last accessed 10 July 2020]. The images were taken at MFS's plant nursery in Maffra, Victoria, in the Gippsland Shire of Wellington (37.97208°S 146.99547°E). After photographing the specimen, MFS returned to collect the bee but it had already departed. MFS has kept a continued watch for the return of this species but there has been no further sighting at the nursery from the original observation date.

The second sighting of *A. manicatum* was through a Facebook group called "Bees in the Burbs" (<https://www.facebook.com/groups/Beesintheburbs>) [last accessed 24 July 2020] created by Kit Prendergast in August 2016. On 7 March 2020 (Facebook 2020a), PL posted an image of a bee sitting on a leaf and asked "What is this hovering on my borage please?" K LW identified the bee as the invasive *A. manicatum*. Through a Facebook conversation with PL, K LW was provided the location of the post image and given permission to visit and to collect specimens. K LW travelled to Sale on 9 March 2020 arriving at PL's home about 2pm. Earlier that day, PL had collected a male specimen in a glass jar and placed it in the freezer of her fridge. Over a 20-minute period, K LW then collected, by sweep net, another one male and one female specimen of *A. manicatum*. Both specimens were flying around and landing on flowering sage (*Salvia* sp. (Lamiaceae)). Despite the backyard garden having a wide selection of flowering plants, the *A. manicatum* specimens were flying around only the sage flowers and landing on the leaves. K LW and PL watched the bees fly back and forth over PL's back fence but no attempt was made to locate the nest site. However, the property behind PM's back fence has a set of well-established accommodation units with no sign of recent renovation activity that may have transported brood cells of *A. manicatum* to this area. The following day, PL emailed K LW to say several more specimens of *A. manicatum* continued to visit the same plants during that afternoon and the next day. K LW sought PL's permission to enter her Facebook image into iNaturalist (<https://www.inaturalist.org/observations/39830063>) [last accessed 10 July 2020] and this record was then uploaded to ALA (<https://biocache.ala.org.au/occurrences/ed10199d-9e59-482d-b640-9bd5b566d61d>) [last accessed 10 July 2020]. The distance between the first record in Maffra and the second record in Sale is less than 20 kilometres.



Figs 5, 6. *Anthidium manicatum* female views. (5) head front; (2) dorsal metasoma. Photos by KLW.

Diagnosis

Since 2000, there have been two exotic carder bee species introduced unintentionally to Australia—the African carder bee, *Pseudoanthidium* (*Immanthidium*) *repetitum* (Schulz 1906) (Anthidiini) and the European wool carder bee, *A. manicatum*. In Australia, Anthidiini has two named native Australian species: *Anthidiellum* (*Pycnanthidium*) *melanaspis* Cockerell, 1929 and *Anthidiellum* (*Pycnanthidium*) *turneri* (Fries, 1909); both species are restricted to Queensland and are uncommon. These four species are the only Megachilidae in Australia which have yellow or white pigmented bands on their metasomal tergal segments; in all other Australian Megachilidae, the metasomal bands are formed by coloured, tomentous hair.

(Description modified from Gonzalez and Griswold 2013; For full synonymy list see Niu *et al* 2020).

Female body length 9.2–12.2 mm; forewing length 7.8–8.9 mm. Male body length 12.3–17.7 mm; forewing length 8.2–10.8 mm.

Both sexes of *A. manicatum* can be distinguished from all other *Anthidium* and the Australian *Anthidiellum* Cockerell, 1904 species by terga with broadly interrupted yellow bands, becoming progressively closer on apical segments which form a distinctive black, broad V-shaped pattern across terga (Figs 2, 6). Both sexes are dark brown to black coloured except for light reddish-brown coloration on the distal two-thirds of the middle and hind femora, and yellow maculation throughout their body (Figs 1, 3, 4). Females (Figs 3, 5, 6) have a character combination of: underside of flagellum 2 round; propodeal enclosure tessellate but with distinct punctures deeper; basal half of T2 surface smooth, shiny clypeus weakly convex with strong teeth or tubercles on convex apical margin and clypeus covered with simple, apical, curly hairs on supraclypeal area and frons; strong outer ridge on mandible (Fig. 5); light ferruginous pubescence, except for paler hairs on the sides of the thorax and S1–S5 (Fig. 3); dense tomentum on the outer basitarsi; hind tibia with anterior carina present; T1–T5 discal areas narrow, weakly elevated with weakly imbricate and shiny areas between coarse punctures; small median notch in posterior margin of metasomal T6 (Fig. 6). Males (Figs 1, 2, 4, 7) have a character combination of: apex of metasoma curved downwards; T2–T5 with strong, lateral protuberances and with tufts of curved, long ferruginous or pale hairs on the lateral protuberances of T2–T5 (Fig. 4), T6 lateral spine is curved, longer, and more stout than T7 median spine, spiniform projections on T7; S6 with apical margin broadly rounded; S8 longer than broad (Fig. 7);

Discussion

The Australian bee fauna comprises almost 1,700 species (AFD 2020a). There are now seven non-native species currently established in Australia, three in both Apidae and Megachilidae and one in Halictidae. These species can be defined as ranging from adventive to invasive (Colautti and MacIsaac 2004).

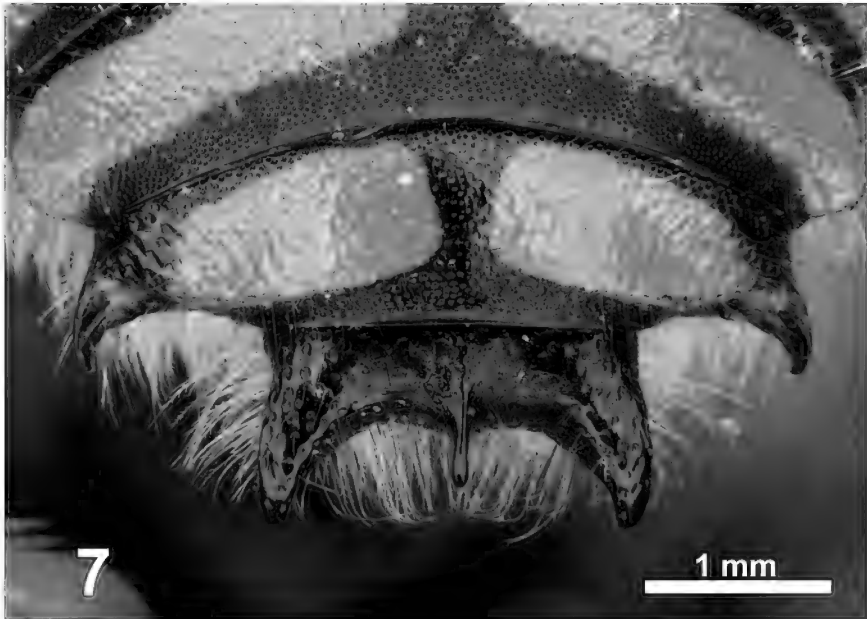


Fig. 7. *Anthidium manicatum* male. T6–T7 metasomal spines. Photo by KLW.

Apis mellifera (Apidae), the eusocial European honeybee, was the first imported bee to Australia in 1822 (Hopkins 1886). Feral colonies had become widespread by 1860 (Laurie 1886) and the species can now be found throughout much of Australia (Oldroyd *et al.* 1997, ALA 2020). It has had ecological impacts on the native Australian flora and fauna as well as economic and health impacts on human society, both in positive and negative ways and should be termed an invasive species (Paini 2004, Moritz *et al.* 2005). *Apis cerana* Fabricius, 1793 (Apidae), the Asian honeybee, was introduced accidentally to Australia in 2007 and has now become established locally around the Cairns region in Queensland (Koetz 2013). It should be categorised as an adventive species. *Bombus terrestris* (Linnaeus, 1758) (Apidae), the eusocial large earth bumblebee was introduced accidentally to Hobart, Tasmania in 1992 (Hingston 2007) and although now widespread throughout Tasmania, the species has not yet reached mainland Australia. Hingston (2007) raised ecological concerns about *B. terrestris* and this species has been listed in New South Wales and Victoria as a key threatening process or a potentially threatening process (Moore and Gross 2012). It should be considered an invasive species. *Megachile (Eutricharaea) rotundata* (Fabricius, 1787) (Megachilidae), the solitary alfalfa leafcutter bee, was first imported from New Zealand to Australia in 1987 near Keith, South Australia to improve the pollination of alfalfa (Woodward 1996). A further 1 million *M. rotundata* leafcutter bees from Canada were imported in 2002/03, 2003/04 and 2004/05 during the Australian lucerne growing seasons (Anderson 2006); however, this

species has not readily established and there are no recent Australian records for this species. It should be regarded as an imported species. In 2004, a species of *Halictus* Latreille, 1804 (Halictidae), a genus previously unknown in Australia, was introduced accidentally to the Upper Hunter Valley region of New South Wales. Initially, the species was identified as the emerald furrow bee, *Halictus smaragdulus* Vachal, 1895, native to the western Palaearctic (Gollan *et al.* 2006); however, the species was later re-identified as *Seladonia hotoni* (Vachal, 1903) (Halictidae), a native South African species (Batley *et al.* 2016). The population remains locally in the Upper Hunter Valley and it should be termed an adventive species. The accidentally introduced African carder bee, *P. repetitum* nests communally and often uses human-modified structures such as wooden boxes and sliding window frames, (Queensland Museum 2010) as well as artificial bee hotels (Makinson *et al.* 2016). A native to South Africa, it was first recorded near Brisbane in 2000 (Burwell and King 2000), then south to Sydney, New South Wales in 2008 and Melbourne, Victoria in 2014, north to Clermont, Queensland, in 2015 (Baumann *et al.* 2016) and had travelled across the continent to near Perth by February 2020 (Prendergast 2020). Although this species is restricted mainly to South Africa and Australia, at this stage should be termed adventive, bordering on invasive. And finally, *A. manicatum* is the latest non-native bee species recorded in Australia. The rapid spread of this species world-wide, aided by human transportation to cross major barriers, its ability to adapt to a range of climatic conditions and the aggressive behaviour of males to other bees around female host nesting plants has the species termed as invasive (Strange *et al.* 2011). It's only limitation appears to be access to Lamiaceae for nesting material.

The appearance of the first image record of *A. manicatum* was concerning but no further activity was observed and no specimen was collected. However, the second record, some 15 months later, where specimens of both sexes were photographed, observed and collected over several days, confirmed that *A. manicatum* now appears to be established in the Gippsland area around the Maffra to Sale region in eastern Victoria, Australia.

The establishment of *A. manicatum* in Australia raises several questions. Considering the rapid and transcontinental spread across Australia of the African carder bee, *P. repetitum*, what will be the potential habitat range for *A. manicatum*? The documented spread of *A. manicatum* across the USA within a 50-year period (Strange *et al.* 2011) and widespread distribution throughout New Zealand in less than 10 years (Soper and Beggs, 2013) was due primarily to the bee nesting in human-modified structures combined with human-mediated transportation through the building and plant nursery trades. We speculate that the recent Australian population of *A. manicatum* may have originated in New Zealand due to the significant trade and movement between these two countries. However, neither Sale nor Maffra are near major sea ports or airports, so infested material may have been transported to this area. Whether the Maffra-Sale establishment was the result of a single or multiple arrivals of *A. manicatum* cannot be determined.

Anthidium manicatum does not effectively cross major barriers and is a synanthropic species usually found in urban settlements. Parallels occur with the Australian transcontinental spread of *P. repetitum* within a 20-year period primarily due to its use of human-modified structures in which to nest (Prendergast 2020) and is generally associated with urban settlements (Makinson *et al.* 2016). Although climatic conditions in general do not appear to be a significant barrier to the spread of *A. manicatum*, southern and eastern Australia offer *A. manicatum* suitable climatic regions (BOM 2001). Importantly, Australia offers abundant available host nesting plants from the extensive use of native and exotic Lamiaceae ornamentals in urban gardens. PlantNet (FloraOnline 2020b) lists 44 genera and c. 750 species of Lamiaceae in Australia.

There are differences between the two non-native Anthidiini species in Australia in terms of communal versus solitary nesting. *Pseudoanthidium repetitum* nests communally so that relatively large numbers of bees can be transported to new locations. Michener (1968) reported a nesting site which contained almost 1,800 cells and cocoons from Natal, South Africa. Like *P. repetitum*, *A. manicatum*, nests in human-modified structures; however, *A. manicatum* also nests in hollow plant stems. *Anthidium manicatum* is a solitary nesting bee, therefore smaller numbers of cells and cocoons will be transported to new locations, and while *A. manicatum* nests in human-modified structures that can aid its spread, it also nests in wood cavities and plant material that are amenable to transportation through the plant nursery trade. However, we suggest that once well established, *A. manicatum* has the potential to spread across southern and eastern Australia with a range similar to what *P. repetitum* has achieved.

A second question concerns the environmental impacts of this invasive species in Australia. These environmental impacts include nesting and floral competition with native bees, especially in the family Megachilidae; and, the proliferation of invasive weeds.

Although the long-tongue bee family Megachilidae is one of the largest bee families world-wide, the Australian bee fauna is dominated by the short-tongue bee families Colletidae (910 species) and Halictidae (384 species) and Megachilidae has only 154 named Australian species (AFD 2020b). Australian Megachilidae, in particular *Megachile* Latreille, 1802 leafcutter and resin bees, will sometimes nests in human-modified structures, such as in hollow bamboo plant stems (Facebook 2020b), in artificial bee hotels (Facebook 2020c, Aussie Bee 2020) as well as odd places such as inside of the fingers of abandoned garden gloves (Facebook 2020d). However, *A. manicatum* is significantly larger in body size than almost all above ground nesting Australian Megachilidae, implying that there should be little to no competition for nesting sites in wooden cavities, hollowed plant stems or artificial bee hotels.

Recent studies on the closely related African carder bee, *P. repetitum*, in Australia found no evidence of adverse effects on the native bee fauna (Prendergast 2020) in terms of native bee abundance, species richness or diversity (Makinson *et al.*

2016). Soper and Beggs (2013) studied the impacts and effects of *A. manicatum* on New Zealand's native flora and fauna and concluded the invasive bee did not present a major threat. The plant families preferred by *A. manicatum* were shared mainly with other invasive bees such as *A. mellifera* and *Bombus* rather than with native New Zealand bees and 80% of the floral visitations were to exotic flora. Interactions with New Zealand bees was primarily with the four native species in the genus *Lasioglossum* Curtis, 1833 (Halictidae) (Donovan 2007, Soper and Beggs 2013). Although Australia has 266 species of *Lasioglossum* (AFD 2020c), none are probably at particular risk as Soper and Beggs (2013) indicated that size alone affects the number and duration of attacks. New Zealand has a significantly smaller bee fauna of just 41 species (Donovan 2007) compared to the Australian bee fauna of about 1,700 species therefore adverse interactions between *A. manicatum* and Australian bees may be more substantial, in particular with *Lasioglossum*, and should be monitored.

Anthidium manicatum is polylectic and undesirable floral visitations is another concern with this bee. The bee has been recorded visiting a wide range of flowering plants; however, several studies have reported the floral preference of *A. manicatum* is primarily for exotic plants in the families Lamiaceae, Fabaceae, Plantaginaceae and Scrophulariaceae. No studies have reported floral impacts or spread of exotic weeds (Strange *et al.* 2011, Soper and Beggs 2013).

We suggest that the success of *Anthidium manicatum* as an invasive species appears to be a combination of several factors. Two significant features are the Megachilidae key innovation of using foreign material in nest construction and the reversal of usual solitary bee behaviours: to recapitulate, both sexes emerge at the same time; females mate continuously throughout the flight season rather than mating once; bias toward higher female sex ratio in some seasons; and, larger males defend and protect female floral resource plants. The ability to establish in different climatic regions, the synanthropic association with human settlements, the use of human-modified structures and spread assisted through human-mediated transportation have all contributed to the invasive success of this species found now on almost all continents of the world.

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TWO NEW SPECIES OF *MACROGLOSSUM* SCOPOLI (LEPIDOPTERA: SPHINGIDAE) FROM PAPUA NEW GUINEA

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Abstract

Macroglossum niuginiensis sp. n. and *M. naispela* sp. n. are described from the Tabubil area of Western Province, Papua New Guinea.

Keywords: hawkmoth, holotype, montane, Pidgin, irrorate, distinct

Introduction

In a paper on the hawkmoths of Western Province, Papua New Guinea, Moulds and Lachlan (1998) illustrated two small species of *Macroglossum* Scopoli, 1777 as *M. caldum caldum* Jordan, 1926 and *M. calescens* Butler, 1882. Further study has revealed that these taxa represent two previously unknown species, which are described below. Terminology for morphological features follows Moulds *et al.* (2020).

Macroglossum niuginiensis sp. n.

(Figs 1, 2)

Type. Holotype ♂, PAPUA NEW GUINEA: SE slopes of Mt Akrik (Ian), 15 km NW of Tabubil, Western Province. 5°10'S 141°9'E, Alt. 1625 m, 9.x.1993, R.B. Lachlan. Holotype deposited in the Australian Museum, Sydney.

Description. Male (Figs 1, 2). Forewing length 19 mm. Antennae dark brown above, lighter brown below; palpi dark brown dorsally mixed with numerous white tipped scales, with a dark brown, thin, triangular lateral stripe to eye; eyes clearly lashed with lateral thin white line immediately above and partially behind eyes; head, prothorax and tegulae dark brown and heavily overlaid by medium brown scales, lightly irrorated with the white tips of the overlaid dark brown scales; tegulae with numerous white tipped scales at distal margins; abdomen medium brown dorsally with black lateral patches from tegulae to posterior edge of segment 5; segment 3 with thin lateral yellowish orange lines; segment 4 with very thin lateral yellowish orange line less than half the size of the yellowish orange lines on segment 3; segment 5 with two quite small, white spots placed mesad toward posterior edge of segment 5; dorsal medium brown region of segments 2 to 5 lightly irrorated with white tipped scales at posterior edges; segment 7 with mesad areas more heavily irrorated with white tipped scales; fantail with medium brown centre, darker scales laterally irrorated lightly with white tipped scales.

Underside of palpi and thorax ventrally with white tipped brown scales superficially appearing as a light dusting of white over dark brown. Abdomen underside ventrally reddish brown with some white scaling on segments 2 to 4 with five well-formed orange-brown lateral spots adjacent to the white tipped abdominal lateral tufts; fantail lighter brown than above.

Forewing upperside ground colour dark brown but heavily overlaid with lighter brown scaling, irrorated lightly with pale bluish white scales that form a faint, compact apical patch with a small, thin streak; another curved subapical band of lightly irrorated pale bluish white scales runs from costa to outer margin down to tornus, pinched thinly in centre of subapical area; additional light bluish white scaling slightly basal of tornus; a narrow, faint, broken, irregular medial band of bluish white scales from costa to inner margin; faint bluish white scaling at base and subbasal area.

Hindwing upperside black with very small, indistinct yellowish orange spot near discal cell and a slightly larger distinct yellowish orange subternal spot with some additional yellowish orange scales reaching inner margin.

Forewing underside ground colour dark brown with lighter brown scaling along costal margin from apex to base; a slightly reddish brown subapical irregular band runs from vein Rs_3 to vein M_1 then becomes marginal from vein M_1 and narrows at CuA_2 . Hindwing underside ground colour dark brown overlaid with lighter brown scaling more so basally; small, distinct, slightly elongated yellowish orange subternal spot does not reach inner margin.

Male genitalia. Not dissected and examined. The author made this decision on the basis that the distinctive, unique external morphological characters displayed by this new species, the holotype's near perfect condition, the DNA barcode provided by the Barcode of Life Data Systems project (BOLD) clearly indicated no close match to another species at 3.7% divergent from its nearest neighbour on BOLD and the fact that the holotype is currently the only known specimen meant that examination of the genitalia and damaging this specimen was, at this point, not essential. Should further male specimens be collected then the genitalia could be examined.

Female. Unknown.

Etymology. *Macroglossum niuginiensis* **sp. n.** is named to honour the country of origin using the New Guinea Pidgin, or simply Pidgin, word for New Guinea which is, "Niugini". Pidgin is an official language of Papua New Guinea and the most widely used language.

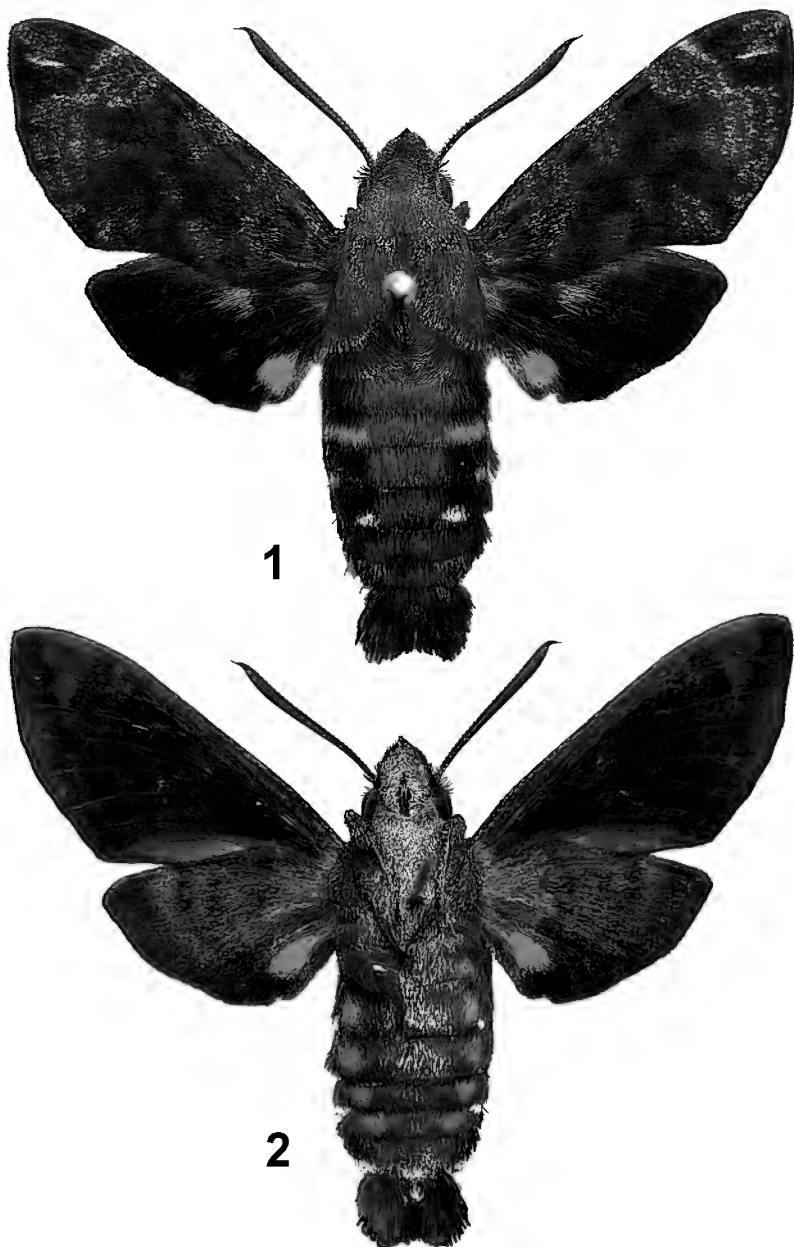
Distribution. At present, *M. niuginiensis* **sp. n.** is only known from the type locality in the western mountains of Western Province, Papua New Guinea.

***Macroglossum naispela* sp. n.**

(Figs 3, 4)

Type. *Holotype* ♀, PAPUA NEW GUINEA: SE slopes of Mt Akrik (Ian), 15 km NW of Tabubil, Western Province. 5°10'S 141°9'E, Alt. 1625 m, 9.x.1993, R.B. Lachlan. Holotype deposited in the Australian Museum, Sydney.

Description. Female (Figs 3, 4). Forewing length 21.5 mm. Antennae filiform, dark brown above, medium brown below; palpi dark brown dorsally with some scattered white tipped scales, a dark brown triangular lateral stripe from palpi



Figs 1, 2. *Macroglossum niuginiensis* sp. n. (1) holotype male upperside; (2) holotype male underside.

tip to eye, lighter brown at eye; eyes lightly lashed with thin white lateral line immediately above and partially behind each eye; head, prothorax and tegulae dark brown and heavily overlaid with medium brown scales, lightly irrorated with the bluish white tips of the dark brown scales; tegulae with numerous bluish white scales at distal margins; abdomen medium brown dorsally with lateral black and yellowish orange patches on segments 3 and 4, yellowish orange patches on segment 4 slightly smaller than those on segment 3, two small white spots mesad toward posterior end of segment 5 with two small, thin bluish white lines at anterior edge and larger lines of bluish white tipped dark brown scales at posterior edge of segment 7; fantail dark brown, irrorated with a few bluish white scales.

Underside of palpi and thorax ventrally white, less so laterally; abdomen white ventrally but irrorated with brown scales on segments 2 to 4, then thin ventral white dusting to fantail; five small pale brown lateral patches with three small white lateral tufts on each side of abdomen; fantail medium brown with darker brown edges.

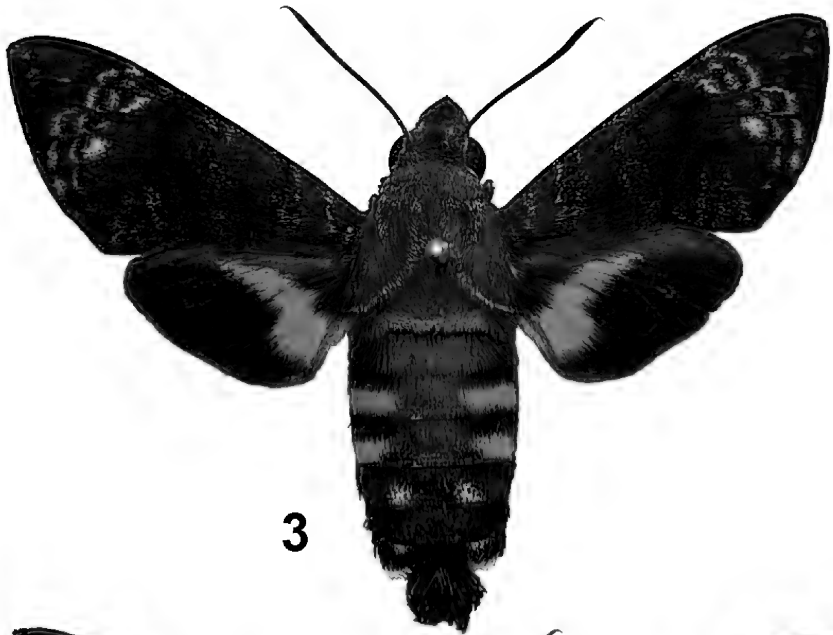
Forewing upperside ground colour dark brown but heavily overlaid with lighter brown scaling; three small irregular bluish white spots in apical region, a curved subapical band of close, parallel lines of crescent-shaped markings from costa to outer margin, two pairs of these markings straighter at outer margin between veins M_2 and CuA_1 , a small, bluish white spot immediately basad of this band is seen between veins M_2 and M_3 , a small irregular tornal patch of bluish white scales; a narrow vestigial, bluish white medial band between costa and inner margin and a similar, second, slightly clearer antemedial band; a small, thin, subbasal band of bluish white scales from costa to inner margin.

Hindwing upperside uniformly black, an uninterrupted yellowish orange median band beginning at vein M_1 as a narrow point and extending down to the inner margin, its outer margin is abruptly angled at about 90° with a lobe-like extension along the inner margin towards, but not reaching, the tornus.

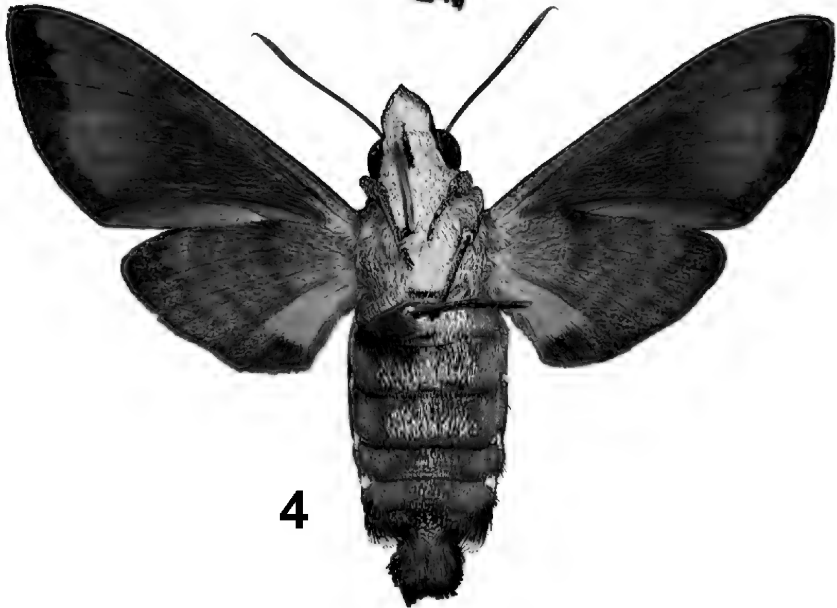
Forewing underside with blackish brown marginal band, extending slightly basally between veins Rs_4 and M_2 , reddish brown ground colour from costa to vein CuA_2 between postmedian and submarginal area, basal half of wing dark brown overlaid with very fine, pale yellow hair-like scales, a cluster of much larger yellow hair-like scales at base.

Hindwing underside basal third with mixture of pale yellow and very light brown scales, distal two thirds darker brown with distally curved postmedial lighter brown band edged basally and distally by thin, faint, curved, dark brown lines, a faint medial distally curved dark brown line and a slightly wider, darker, distally curved antemedial band, lines and bands run from costa to yellow basal area, yellow basal area extends from just above vein $1A+2A$ to just below but does not reach inner margin or tornus.

Male. Unknown.



3



4

Figs 3, 4. *Macroglossum naispela* sp. n. (3) holotype female upperside; (4) holotype female underside.

Etymology. *Macroglossum naispela* **sp. n.** is named using the New Guinea Pidgin, or simply Pidgin, word “naispela” meaning nice, pretty or beautiful, to describe its overall appearance.

Distribution. At present, *M. naispela* **sp. n.** is only known from the type locality in the western mountains of Western Province, Papua New Guinea.

Discussion

Macroglossum niuginiensis **sp. n.** was first noted and illustrated by Moulds and Lachlan (1998) as *M. caldum*. After examining the holotype of *M. caldum* in D'Abrera [1987] as well as additional large-scale photographs of the holotype obtained more recently from the NHM, London, it was very clear that *M. niuginiensis* **sp. n.** was a distinct new species. It is unique in having two separate, diminutive yellowish orange spots on the hindwing instead of the usual clearly visible yellowish orange band of varying widths seen on most species of *Macroglossum*. It is interesting to note the unusual pale bluish white scaling pattern on the forewings of *M. niuginiensis* **sp. n.** is very similar to those seen on *M. caldum* from south-eastern Papua New Guinea, *M. calescens* from New Britain and New Ireland in PNG and *M. cadioui* Schnitzler and Speidel, 2004 from Sulawesi. However, the appearance of the two lateral abdominal orange lines and the mesad white dots below them differ from the other three species. Also, there is no dark brown median stripe on the palpi, head and prothorax as clearly seen in the other three species. The outer margin of the forewing of *M. niuginiensis* **sp. n.** is more distally curved than seen in *M. caldum* or *M. cadioui*.

Macroglossum naispela **sp. n.** was also first noted and illustrated by Moulds and Lachlan (1998) but as *M. calescens*. However, *M. calescens* has three yellowish orange lateral abdominal patches, dark grey palpi, head and thorax with a clear black median stripe and the yellowish orange hindwing band is larger reaching from the costa to inner margin. While *M. caldum* is also similar to *M. naispela* **sp. n.** it too has dark grey palpi, head and thorax with a black median stripe, and a yellowish orange hindwing band that runs from the costa to the inner margin. *M. naispela* **sp. n.** has the unusual bluish white forewing markings seen on both *M. caldum* and *M. calescens* but the subapical bluish white crescent-shaped markings seen on *M. naispela* **sp. n.** are distinctly different to the subapical markings on those two species. Interestingly, *M. cadioui* from Sulawesi is quite similar with the bluish white forewing markings but its subapical markings form unbroken, straighter lines in parts, whereas these markings in *M. naispela* **sp. n.** are more curved and separated at the veins that pass under these markings. *M. cadioui* differs from *M. naispela* **sp. n.** in having a dark brown dorsal medial stripe on the palpi, head and thorax; a wider and longer yellowish orange band on the hindwing; no mesad bluish white spots on segment 5; on the underside of the hindwing the postmedial, medial and antemedial dark brown bands are more robust and irregular in shape; the white dusting on the underside of the abdomen is narrower and longer.

Given that the author lived in the Tabubil region of Papua New Guinea for several years and regularly surveyed various sites between 700 m and 2200 m, it is surprising that only a single specimen of each of the new species was collected at the same mine test drilling site on a very remote mountain side at 1625 m. This may indicate that both of the new species are not attracted to light readily, like many species of *Macroglossum*, or it is a montane species, or both. Unfortunately, the drill site is now fully overgrown and no longer accessible.

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RELATIONSHIPS OF THE GENUS *CASERUS* DAJOZ, 1969 (COLEOPTERA: LATRIDIIDAE), WITH A NEW AUSTRALIAN SPECIES

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Abstract

The Brazilian genus and species *Caserus convexus* Dajoz (1969) is transferred from Mycetophagidae to Latridiidae, based on Mexican specimens closely matching the figures of Dajoz, but differing in the tarsal formula (3-3-3 instead of 3-4-4). Detailed characters are given which separate the genus from any member of the Mycetophagidae while matching those of the latridiid subfamily Corticariinae. The Mexican specimens are described in detail, and a new species of this genus, *Caserus australiae* sp. n., is described from south-western Australia.

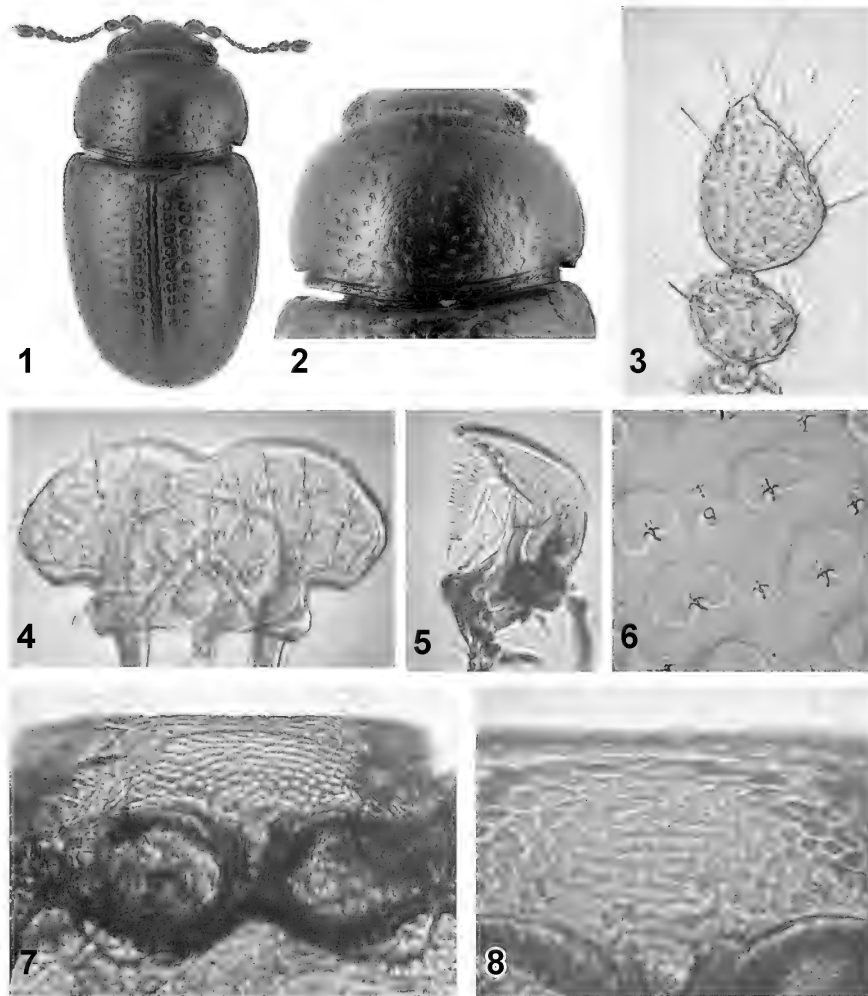
Keywords: Taxonomy, Coleoptera, Mycetophagidae, Latridiidae, morphology.

Introduction

The genus and species *Caserus convexus* Dajoz, 1969, is based on a single specimen of unknown sex from São Tomé, Minas Gerais, Brazil. The description is relatively complete, except for mouthparts or other characters requiring dissection, and illustrations are given for dorsal habitus, with pronotal and elytral punctation, ventral surfaces, lateral view, protarsus and antenna. Although the mid and hind legs are not illustrated, the tarsal formula is said to be 3-4-4, and this feature, combined with globular, very slightly separated procoxae and 11-segmented antennae, are used as evidence of a relationship to the family Mycetophagidae, and in particular members of the European genus *Esarcus* Reiche, 1864. The species is similar to at least some esarcines in general form and in the shape of the prothorax, as illustrated by Dajoz (1964, p. 8, fig. 1), there are, however, a number of important differences which are discussed below.

Several years ago, the author examined specimens extremely similar to the figures of *Caserus* Dajoz, 1969 and certainly the same or a closely related species from Oaxaca and Chiapas, Mexico, but these specimens had 3-3-3 tarsi and other features which place them within the coccinelloid family Latridiidae. Recently, another, slightly smaller species in the same genus was discovered from Kerragullan, south-west of Perth, Western Australia.

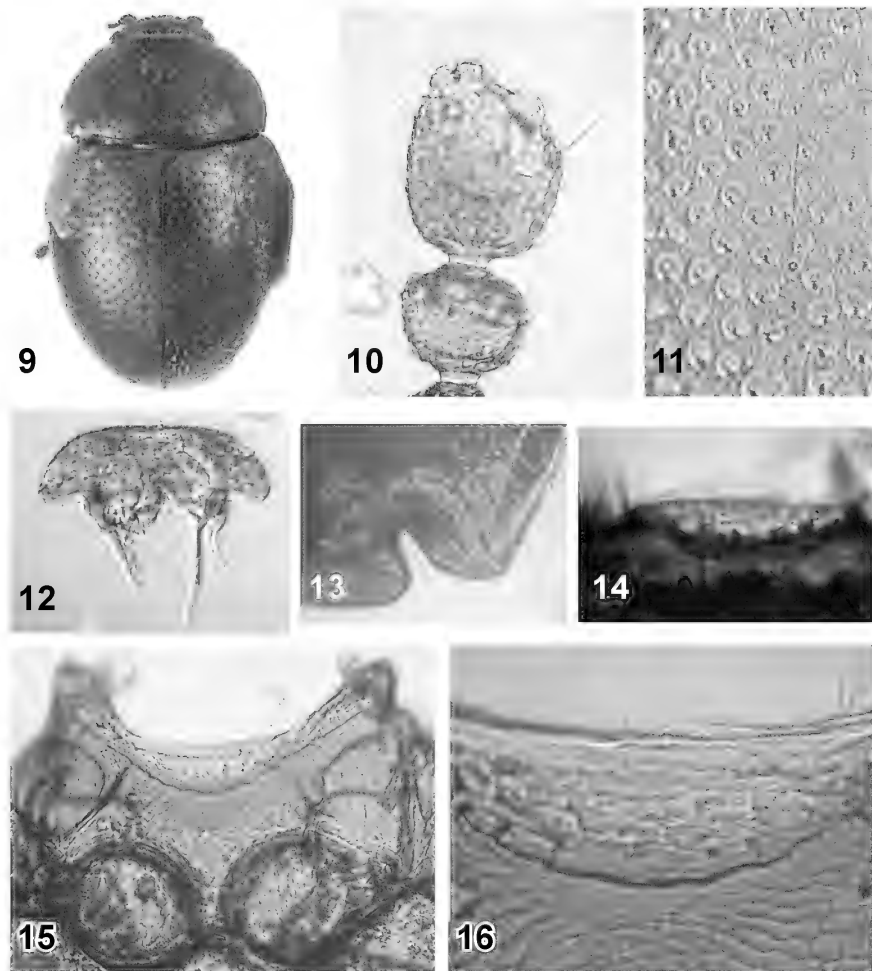
In the following paper, the genus *Caserus* is redescribed and transferred to the latridiid subfamily Corticariinae, and the new Australian species is described. The Mexican species is tentatively identified as *Caserus convexus*, considering the number of similarities to figures of the Brazilian type and assuming that this species is one of many widely distributed small Neotropical species. Examination of the Dajoz type, if it can be found, is considered impossible at the present time and the website of the Muséum National d'Histoire Naturelle was found to be unhelpful. It is assumed here, however, that the mid and hind legs of the type were either absent or 3-segmented.



Figs 1–8. *Caserus australiae* sp. n.: (1) holotype ♀ (0.86 mm), habitus, dorsal; (2) same, head, pronotum and elytral bases; (3–8) paratypes: (3) apical antennomere; (4) labrum; (5) mandible; (6) elytral punctation and vestiture; (7) mesoventrite; (8) anterior edge of mesoventrite without procoxal rest.

Materials and Methods

Most of the terms used in the present manuscript are based on those in Lawrence *et al.* (2011) and Lawrence and Ślipiński (2013), as well as general works on Latridiidae, including Belon (1897, 1909), Hinton (1945), Andrews (2002), Hartley and McHugh (2010). Head length excludes the labrum and head width is that immediately behind eyes. Lengths of the mesoventrite and metaventrite exclude



Figs 9–16. *Caserus convexus* Dajoz: (9) habitus, dorsal (1.05 mm); (10) apical antennomere; (11) elytral punctation and vestiture; (12) labrum; (13) left posterior pronotal angle, showing notch; (14) submentum and gular region; (15) mesoventrite; (16) anterior edge of mesoventrite with prothoracic rest.

the posterior and anterior intercoxal processes, respectively. Habitus images were photographed at the Australian National Insect Collection in Canberra using a Visionary Digital Imaging System (Dun Inc.) <http://www.duninc.com/dun-inc-microscope.html>, a Canon camera with Visionary Digital lift and Canon MPE 65mm lens plus extender. Images of genitalia and some other structures were made with a Dino-Eye AM4023XC Eyepiece Camera attached to both compound and dissecting scopes and DinoCapture 2.0 software. These images were basically

snap shots and did not involve image stacking. All specimens studied have been deposited in the Australian National Insect Collection (ANIC), Canberra, ACT, Australia.

Family Placement and Relationships

Except for the apparent 3-4-4 tarsal formula, which may well be erroneous, since the meso- and metatarsi were not illustrated and all tarsi are 3-segmented in the Mexican specimens mentioned above and described below, there is little other evidence for placing the Neotropical genus *Caserus* in the family Mycetophagidae. Based on data included in Lawrence *et al.* (1999) and on dissected specimens, this genus differs from all Mycetophagidae and resembles members of the latridiid subfamily Corticariinae in the following respects: 1) head with a broad neck and short temples (present only in the mycetophagid subfamily Bergininae); 2) cervical sclerites absent; 3) procoxae with long, concealed lateral extensions; 4) procoxal cavities externally closed by the meeting of the prosternal process and hypomeral postcoxal processes; 5) mesocoxal cavities closed laterally by the meeting of meso- and metaventrites; 6) intercoxal process of first abdominal ventrite truncate (acute or at most rounded in Mycetophagidae); 7) aedeagus of a highly modified ring type (rather than of the tenebrionoid type with basale and articulated apicale); 8) ovipositor without paraprocts, coxites, styli or bacula.

Within the family Latridiidae, *Caserus* has the following characteristics of Corticariinae: 1) labrum on the same plane as the clypeus and not forming a deep groove; 2) prosternal process strongly narrowed at middle, so that procoxae are subcontiguous; 3) head never dorsally sulcate or carinate; and 4) elytra never with carinae or costae.

Family Latridiidae Erichson, 1842

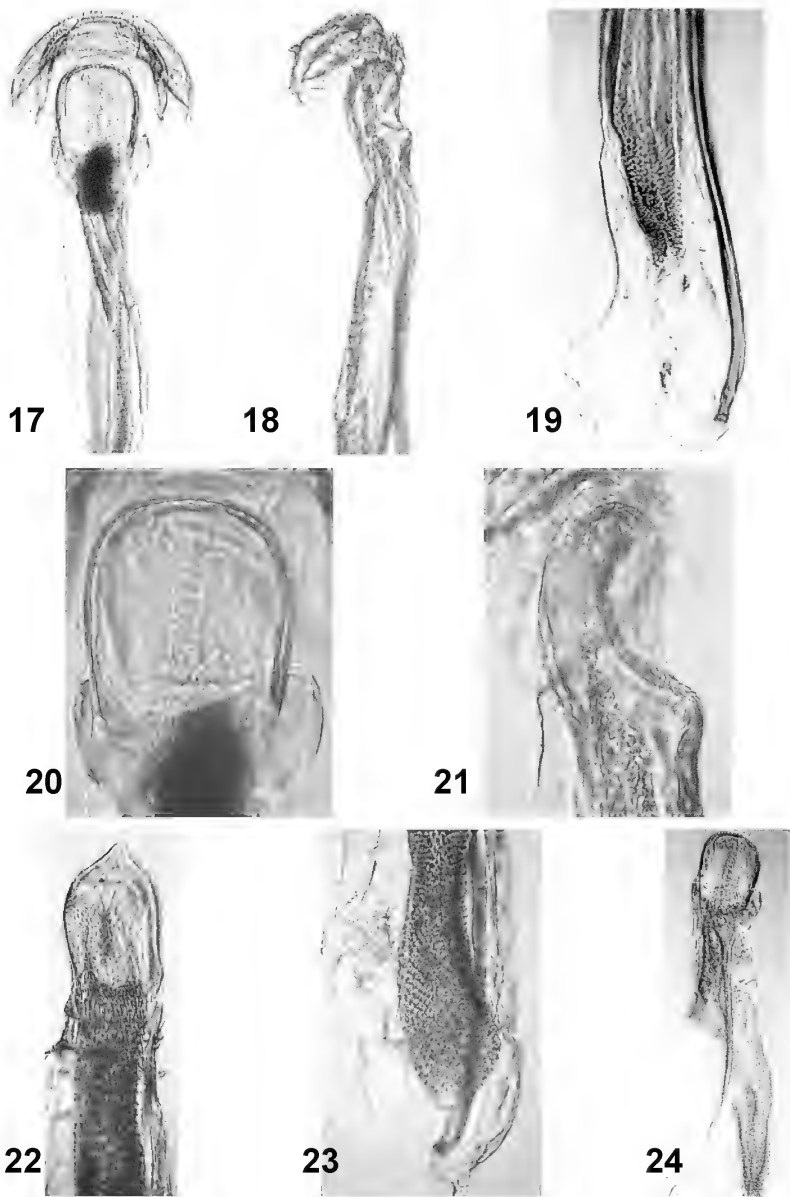
Subfamily Corticariinae Curtis, 1829

Genus *Caserus* Dajoz, 1969

Caserus Dajoz, 1969: 79. Type species: *Caserus convexus* Dajoz, 1969,

Diagnosis. The genus differs from *Corticaria* Marsham, 1802 and *Cortinicara* Johnson, 1975 and resembles *Melanophthalma* Motschulsky, 1866 and *Bicava* Belon, 1884 in having a distinct suture between the submentum and the gular region (Fig. 14). Although the short, broad body form (Figs 1, 9) is similar to some *Corticaria*, the dorsal vestiture is much shorter, the lateral pronotal margins are not denticulate and the beetles are flightless.

Redescription. Length 0.80 to 1.15 mm. Body short and broad, 1.5 to 1.7 times as long as wide, moderately to strongly convex and dorsally clothed with fine hairs, shorter than the punctures within which they arise. Head relatively short and broad, without neck or temples; posterior edge above occipital foramen truncate. Antennal insertions widely separated and exposed. Antennae about 1.5 times as long as head width, 11-segmented with globular scape and loose, 3-segmented club. Eyes 0.25–0.3 times as long as head width, moderately strongly projecting,



Figs 17–24. *Caserus* spp. males: (17–21, 24) *Caserus australiae* sp. n.: (17) abdominal apex, dorsal (faecal mass near end of rectum); (18) abdominal apex, lateral (with rectum removed); (19) anterior portion of genitalia; (20) anterior portion of aedeagus, dorsal; (21) anterior portion of aedeagus, lateral; (24) entire aedeagus and internal sac; (22, 23) *Caserus convexus* Dajoz: (22) anterior portion of aedeagus; (23) posterior portion of aedeagus.

coarsely faceted, with short interfacetal hairs. Mandible (Fig. 5) about 1.4 times as long as wide; outer edge with notch near base, then straight almost to apex where it abruptly curves mesally; apex unidentate; cutting edge with 4 distinct teeth; mola well-developed and microtuberculate; prostheca extending almost to apex, membranous with multicrenulate edge lined with short to long setae. Apical maxillary palpomeres fusiform, narrowly rounded at apex. Submentum separated by suture from gular region (Fig. 14); gular sutures absent. Pronotum about 0.5–0.6 times as long as wide, widest at middle; anterior angles not or barely produced; lateral margins narrow but visible from above; posterior edge with pair of deep notches near posterior angles (Figs 1, 2, 13). Prosternum slightly shorter than procoxal cavities. Scutellum minute. Elytra about 1.0–1.2 times as long as wide and 2.1–2.4 times as long as pronotum; moderately to strongly convex, with punctation confused or subseriate. Mesoventrite about 0.5–0.6 times as long as wide, with or without anterior prothoracic rest. Metaventrite 0.35–0.40 times as long as wide, without discrimen, with or without postcoxal lines behind mesocoxal cavities. Metacoxae separated by about 1.5–1.8 times the shortest diameter of one. Abdominal ventrite 1 much longer than shortest distance between meso- and metacoxal cavities twice as long as ventrites 2 and 3 combined. Male abdominal apex and aedeagus as in Figs 17–24.

Key to the species of *Caserus* Dajoz

- 1 Length greater than 0.9 mm; body (Fig. 9) less than 1.55 times as long as wide; anterior edge of labrum (Fig. 12) without median emargination; terminal antennomere (Fig. 10) apically subtruncate with several sensory papillae; elytra less than 1.1 times as long as wide, with confused punctation (Figs 9, 11); anterior edge of mesoventrite with prothoracic rest (Figs 15, 16); metaventrite without postcoxal lines behind mesocoxal cavities; metanepisternum widest anteriorly; Neotropical region.....*C. convexus* Dajoz
- Length less than 0.9 mm; body (Fig. 1) more than 1.55 times as long as wide; anterior edge of labrum (Fig. 4) with median emargination; terminal antennomere (Fig. 3) subacute, without sensory papillae; elytra more than 1.1 times as long as wide, with seriate punctation (Figs 1, 6); anterior edge of mesoventrite (Figs 7, 8) without prothoracic rest; metaventrite with paired, broadly curved postcoxal lines behind mesocoxal cavities; metanepisternum widest at about middle; Australia.....*C. australiae* sp. n.

Caserus convexus Dajoz, 1969

(Figs 9–16, 22, 23)

Caserus convexus Dajoz, 1969: 80.

Holotype: São Tomé, Brazil, A 621 (MNHN); not examined.

Material examined. **Mexico**: Chiapas: 12 mi. NW Ocozocoautla, 3200 ft. 4–5.ix.1973, leaf litter, forest floor, A. Newton coll. (1, ANIC); Oaxaca: 1 mi. E Reforma, 100 ft., 15.viii.1973, A. Newton, coll. (4, 1 completely dissected, ANIC).

Redescription. Length 1.00–1.12 mm (1.11). Body 1.47–1.52 (1.50) times as long as wide; greatest depth 0.61–0.65 (0.63) times elytral width; colour uniformly dark reddish-brown. Head 0.75 times as long as wide. Eyes 0.3 times as long as head width. Antennal insertions exposed and widely separated. Labrum 0.6 times as long as wide, with sides weakly curved and slightly converging to subtruncate apex. Anterior edge of labrum subtruncate. Antenna 1.45 times as long as head width; terminal antennomere apically subtruncate with several sensory papillae. 11 subtruncate apically with several sensory papillae. Apical maxillary palpomere 2.25 times as long as wide. Mentum 0.70 times as long as wide. Pronotum 0.51–0.58 (0.55) times as long as wide, widest behind middle; anterior edge truncate, anterior angles slightly produced forward; disc finely and sparsely punctate with punctures slightly smaller than eye facets and usually separated by one to one and a half diameters and interspaces finely reticulate and shiny. Prosternum in front of coxae 0.80 times as long as mid length of procoxal cavity, slightly convex. Prosternal process strongly narrowed to about middle, then expanded to truncate apex. Elytra 1.03–1.07 (1.05) times as long as combined width and 2.22–2.40 (2.31) times as long as pronotum; anterolateral angles broadly rounded; disc strongly convex, punctuation confused with punctures about 1.5 times as wide as an eye facet and usually separated by less than a one diameter. Mesoventrite 0.50 times as long as wide; anterior edge with large, undivided prothoracic rest. Mesocoxae separated by distance 0.67 times as wide as shortest diameter of a mesocoxal cavity. Metaventrite 0.40 times as long as wide. Metanepisternum 5.3 times as long as wide, widest near apical end and narrowing posteriorly. Metacoxae separated by 1.55 times shortest (longitudinal) diameter of one, each coxa 0.5 times as long as wide. Abdominal ventrite 1 without postcoxal lines. Aedeagus as in Figs 22, 23.

***Caserus australiae* sp. n.**

(Figs 1–8, 17–21, 24)

Holotype: female “32.05°S 115.07°E Kerragullen, nr. Kelmscott WA 16 Sept. 1981 A. Calder / Berlesate ANIC 742 litter sclerophyll forest” (ANIC). *Paratypes:* Australia: Western Australia: same data as holotype (4, 2 completely dissected, ANIC).

Description. Length 0.85–0.87 (0.86). Body 1.63–1.67 (1.65) times as long as wide; greatest depth 0.63–0.70 (0.65) times elytral width; colour uniformly red. Head 0.8 times as long as wide. Eyes 0.25 times as long as head width. Labrum 0.34 times as long as wide, with sides strongly curved and projecting; apex broadly curved with median emargination. Antenna 1.46 times as long as head width; terminal antennomere obliquely truncate, without obvious sensory papillae. Apical maxillary palpomere 2.67 times as long as wide, narrowly rounded at apex. Apical labial palpomere globular, about as long as wide. Mentum 0.56 times as long as wide. Pronotum 0.56–0.62 (0.60) times as long as wide, anterior angles barely produced forward; disc simple, strongly convex, finely and sparsely punctate with punctures slightly smaller than eye facets and usually separated by one to one and a half diameters and interspaces finely reticulate and shiny.

Prosternum in front of coxae 0.86 times as long as mid length of procoxal cavity. Elytra 1.11–1.16 (1.13) times as long as combined width and 2.10–2.27 (2.17) times as long as pronotum; anterolateral angles subangulate; disc moderately convex, punctation seriate with punctures about 1.5 times as wide as an eye facet and usually separated by less than a one diameter. Mesoventrite 0.58 times as long as wide, broadly truncate anteriorly; anterior edge without prothoracic rest. Mesocoxal cavities separated by 0.75 times shortest diameter of a mesocoxal cavity. Metaventrte 0.40 times as long as wide. Metanepisternum 4.5 times as long as wide, widest near middle and subacute anteriorly. Metacoxae separated by 1.82 times shortest (longitudinal) diameter of one, each coxa 0.42 times as long as wide. Abdominal ventrite 1 with broadly curved postcoxal lines. Abdominal apex and aedeagus as in Figs 17–21 and 24.

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The author acknowledges the continued support for his research provided by Dr Adam Ślipiński, the Australian National Insect Collection and CSIRO National Research Collections. Sincere thanks are given to Dr Ślipiński for his help in preparing the plates and to Ms Bronte Sinclair for her help in sending and photographing specimens

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**FIRST HOST RECORD FOR THE AUSTRALIAN
KLEPTOPARASITIC BEE *NOMADA AUSTRALENSIS* (PERKINS)
(HYMENOPTERA: APIDAE) AND A NEW SYNONYMY**

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Abstract

Observations made over several months by one of the authors (MT) revealed a close association between the kleptoparasitic bee *Nomada australensis* Perkins, 1912 and a communal ground-nesting bee, *Homalictus behri* (Cockerell, 1910). This constitutes the first host record for *Nomada* Scopoli, 1770 in Australia. A review of the two putative Australian species of *Nomada* revealed they are conspecific: *Neoceratina rubinii* Rayment, 1930 **syn. n.** is a junior synonym of *Nomada australensis*. *Nomada australensis* is redescribed and mapped resolving confusion over the distribution of this species.

Keywords: brood parasitoid, nesting behaviour, new host record, Halictidae

Introduction

Kleptoparasitic or brood parasite bees are obligate parasitoids of other bee species. Also known as ‘cuckoo bees’, they make no nests of their own and, instead, lay their eggs in freshly provisioned brood cells of a host bee. Usually, the host egg is killed by the cuckoo bee female or by the first instar larva that hatches from her egg. The cuckoo larva then feeds on the host’s provisions (Michener 2007; Danforth *et al.* 2019).

Globally, there are about 20,000 species of bees (Michener 2007) and an estimated 13% of these species are kleptoparasites (Danforth *et al.* 2019). Kleptoparasites represent only 1.3% of Australia’s bee fauna, which comprises 1,654 described species (AFD 2020). This compares to almost 25% of European bees being kleptoparasites (Bogusch *et al.* 2006) with a bee fauna of approximately 2,000 species (Neito *et al.* 2014).

World-wide, there are 761 species of *Nomada* Scopoli, 1770 (Ascher and Pickering 2020). Alexander (1994) undertook a global cladistics analysis of *Nomada* and concluded that it was monophyletic. He recognized 17 species groups and placed *Nomada australensis* Perkins, 1912 in the *furva* group. This species group is the only one represented in Southeast Asia, the Malay Archipelago, New Guinea and Australia and it occurs also in the Palaearctic region. Recorded hosts for European members of the *furva* group are mainly eusocial *Evylaeus* Robertson, 1902 (Halictidae: Halictinae) and these kleptoparasitic bees were bivoltine (Alexander 1994). The *furva* species group members are the smallest of the genus with body lengths generally 5–7 mm.

This paper reports the first host record for an Australian *Nomada* (Apidae: Nomadinae) on an Australian species of *Homalictus* Cockerell, 1919 (Halictidae: Halictinae). Bees of the genus *Homalictus* nest communally with many (sometimes hundreds of) females sharing a single nest entrance (Danforth and Ji 2001; Michener 2007). We review the two putative Australian *Nomada* species and conclude that they are synonymous. We redescribe the one valid species, *N. australensis* and map its distribution.

Methods and Abbreviations

Observations on adult activity reported here were made by MT in his home garden in the suburb of Mundingburra, Townsville, Queensland, from mid-October 2019 to mid-January 2020. MT observed persistent activity of two species of small bees flying around a spot on his back patio in a 5–6 mm wide gap between brick pavers. Some additional observations were made in another garden about one kilometre away. Photographs and specimens of both bees were sent to TFH and K LW who identified the host nesting bee as *Homalictus* (*Homalictus*) *behri* (Cockerell, 1910) (Fig. 8), a communal ground-nesting halictid bee, and its kleptoparasite as *Nomada australensis* (Figs 1–4).

MT used a sweep net to collect bees flying around the nest entrances. He inverted small, clear plastic, containers over nest entrances (Fig. 11) for up to one hour at a time between 7 am and 4 pm to collect and trap emerging bees, completing about 24 hours of exit trapping over several weeks. Over 100 bees were collected by these means with about 90% being *H. behri* and about 10% being *N. australensis* specimens. In the same period, other *N. australensis* specimens were collected from roosts nearby. Collected specimens were mainly observed and released but 10 *N. australensis* and 14 *H. behri* specimens were retained for examination and identification. These specimens were deposited in Museums Victoria entomology collection.

Morphological terminology follows Michener (2007). All live images were taken by MT using a Canon 70D DSLR with Canon 100 mm macro lens and +4 close-up filter. K LW captured the montage images using a Leica M205C microscope and a DFC500 Leica camera. Helicon Focus montaging software was used to construct final images.

Collection abbreviations—ANIC: Australian National Insect Collection, CSIRO, Canberra, Australia; NHMUK: Natural History Museum, London, UK; NMV: Museums Victoria, Victoria, Australia. Other abbreviations—K LW: Ken Walker; MT: Malcolm Tattersall; TFH: Terry Houston; S: Sterna; T: Terga.

Taxonomy

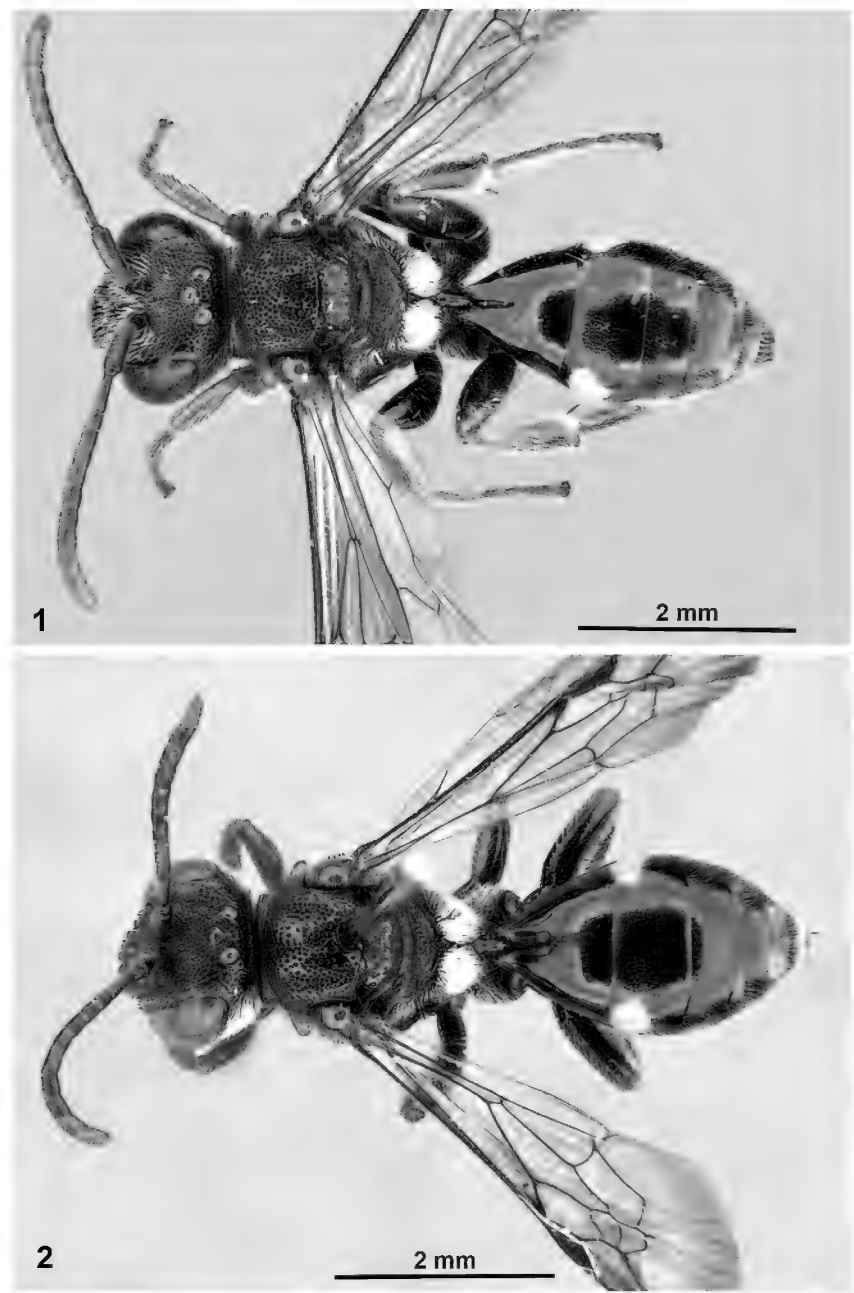
Order Hymenoptera

Family Apidae

Subfamily Nomadinae

Genus *Nomada* Scopoli, 1770

Type species: *Apis ruficornis* Linnaeus, 1758 by subsequent designation Curtis 1833. A complete world species list for *Nomada* is available at ITIS (2020).



Figs 1, 2. *Nomada australensis* dorsal views (1) male; (2) female.

The occurrence of *Nomada* in Australia was first recorded by Perkins (1912) when he described *Nomada australensis* from “Cairns–Kuranda”, North Queensland. In the same paper, Perkins erected the genus *Neoceratina* for a new species *Neoceratina australensis*. Unfortunately, Perkins’ use of the specific epithet “australensis” for two species in different genera has led to some taxonomic confusion. Rayment (1930) described a new species, *Neoceratina rubinii* and compared it with Perkins’ *Neoceratina australensis*. However, as Rayment’s (1930: 56) dorsal habitus illustration showed, the species belonged to the genus *Nomada*. Realising his mistake, Rayment (1935) transferred *Neoceratina rubinii* to the genus *Nomada*. *Neoceratina* was subsequently reduced to a subgenus of *Ceratina* Latreille, 1802 by Hirashima (1971).

Inexplicably, GBIF (2020a) states that *Nomada australensis* is a homotypic synonym of *Ceratina australensis* and the GBIF (2020b) webpage for *N. australensis* includes images of *Ceratina australensis*. Furthermore, 95.9% of the dots on the GBIF distribution map for *N. australensis* represent *C. australensis* records, falsely indicating that *N. australensis* occurs in New South Wales and South Australia. Taking account of these past errors, we find that, in Australia, *Nomada* is confined to North Queensland (Fig. 7).

We have examined high quality museum images for the types of *N. australensis* (NHMUK) and *N. rubinii* (ANIC) and we are confident that these types represent a single species of *Nomada*.

Nomada australensis Perkins

(Figs 1–7, 9–12)

Nomada australensis Perkins, 1912: 116.

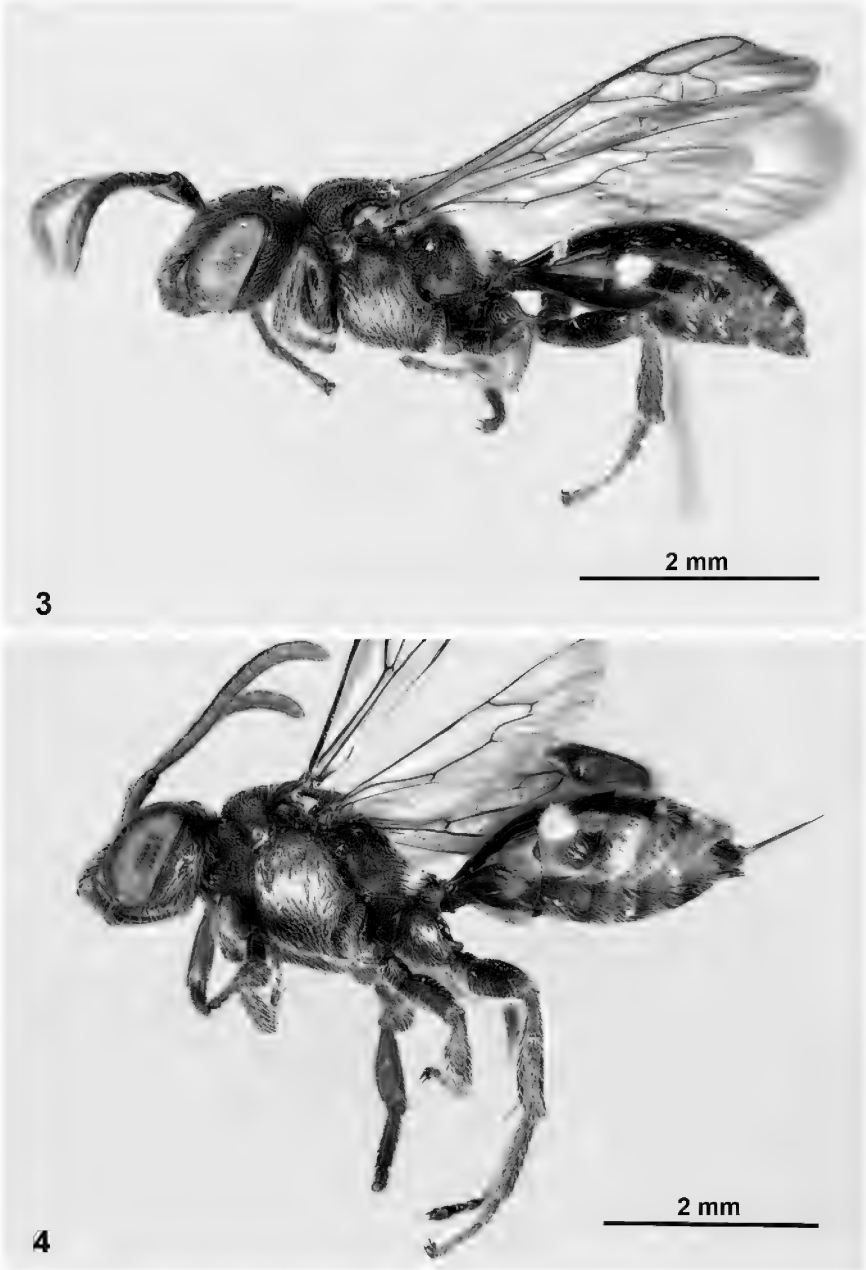
Neoceratina rubinii Rayment, 1930: 55. **syn. n.**

Nomada rubinii (Rayment) 1935: 346.

Material examined

Syntype ♀ of *Nomada australensis* (NHMUK-014025099: record and image URL—<https://data.nhm.ac.uk/object/d0b422ed-16c9-486d-bca9-fa834bac6966/1592956800000>) Cairns–Kuranda, Queensland, 3.02., R.E. Turner 1910-225, B.M. Type 17B.5724a (specimen glued to card, metasoma detached but otherwise specimen intact) (NHMUK). Holotype ♂ of *Neoceratina rubinii* (ANIC Database No 32 065524) Townsville, Queensland, Aug 1920, C.L. Barrett (specimen pinned to cork, missing all right legs) (ANIC).

Other material examined (8♀, 15♂, Fig. 7). *Specimens*: Queensland: 3♀, 7♂, Townsville–Mundingburra, 19.2088S 146.7805E, 14–21 Nov 2019, Malcolm Tattersall, either sweeping around nest entrance (3♀ HYM 91767 to 91769) or roosting on grass heads (7♂, HYM 91770 to 91774; HYM 92015 and HYM 92016) (NMV); 1♀, 2♂, 3km NE Mt Webb, 30 April–3 May 1981, I. D. Naumann (ANIC). *Images*: 2♀, Townsville, 21 Aug 2015 and 16 July 2016, G. Cocks (<https://biocache.ala.org.au/occurrences/27fe160f-6a68-4871-a3bd-994da7f1bc4a> and <https://biocache.ala.org.au/occurrences/dfcaa983-a1e7-4ce3-b6e6-8e8dc9f4bfb5> [last accessed 17 July 2020]); 2♂, Lot 1 Stock Route Alleyway, Hervey Range, 23 Jan 2011 and 18 Oct 2011, G. Cocks (<https://inaturalist.ala.org.au/>



Figs 3, 4. *Nomada australensis* lateral views (3) male; (4) female.

observations/28932502 <https://inaturalist.ala.org.au/observations/28926370> [all last accessed 17 July 2020]]; 2♀, Cairns, 1 Jan 1953, G.B. (MV: HYM 42545–HYM 42546); 1♀, Bloomsbury near Mackay, 17 Aug 2018, R. Richter (<https://inaturalist.ala.org.au/observations/15778475> [last accessed 17 July 2020]); 3♂, Airlie Beach, 3 March 2014, Steve & Alison Pearson (<https://www.flickr.com/photos/72842252@N04/13017692623/> <https://www.flickr.com/photos/72842252@N04/13017899094/> <https://www.flickr.com/photos/72842252@N04/13017555715/> [all last accessed 17 July 2020]).

Description

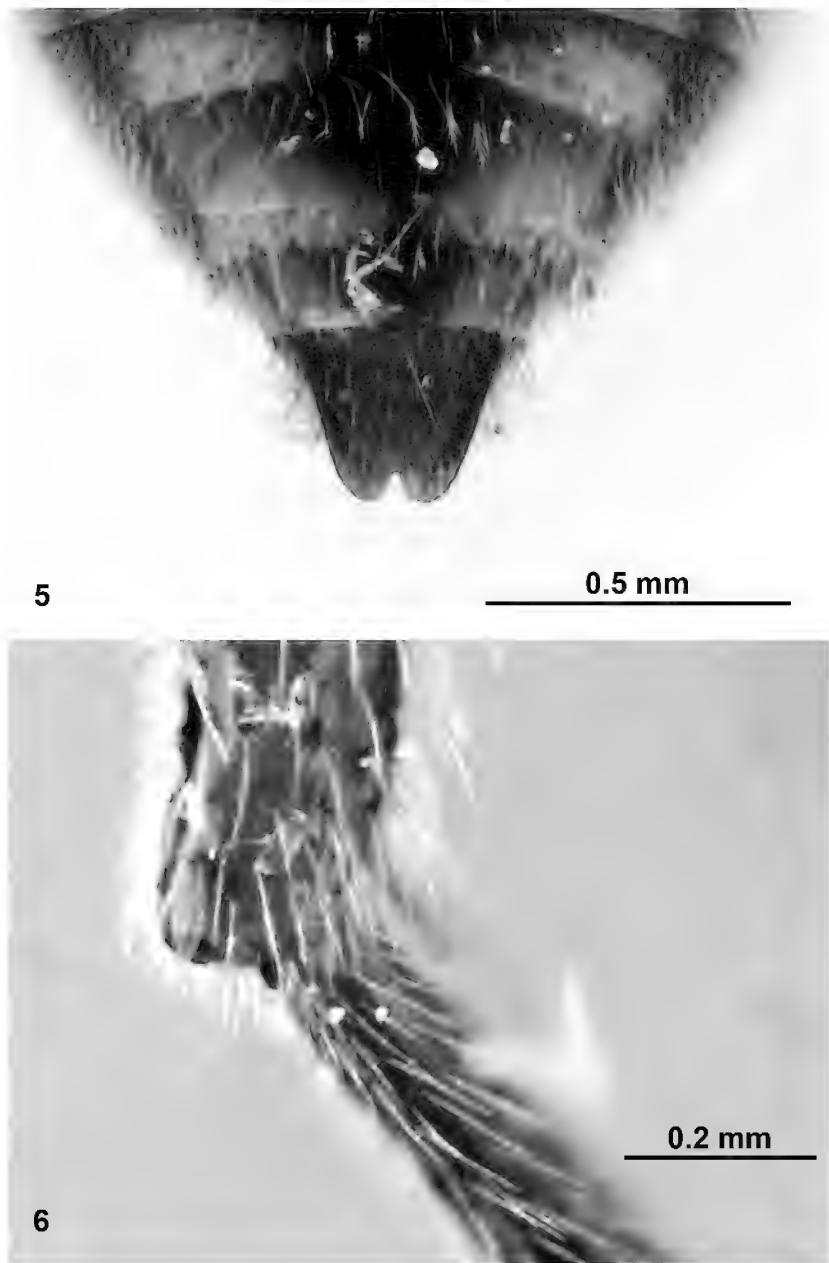
Male

Body length: 4.37–6.03 mm; forewing length 3.51–4.84 mm.

Structure: mandibles long, simple, apically pointed. Malar space with condyle nearly touching ventral margin of eye. Pedicel partly enclosed by scape; F2 about three-quarters length of F1, and slightly shorter than F3; remaining flagellar segments subequal, gradually decreasing in length except F11 nearly twice length of F10. Interantennal area with distinctly raised vertical carina extending vertically almost to midpoint of frons, gradually decreasing in height. Preoccipital margin carinate. Pronotal collar with dorsal margin weakly carinate, straight, reduced almost to nothing at midpoint. Pygidial plate slightly longer than basal width, carinate along margin, and strongly emarginate medially at apex (Fig. 5); Hind tibiae at outer apical margin with two short, stout, semi-translucent, spine-like pegs, slightly shorter than surrounding white hairs, straight and ventrally directed. Hind tibial spurs relatively straight, with outer spur nearly one-fourth shorter than inner. Forewing with three submarginal cells.

Colouration: head and mesosoma predominantly black (Figs 1, 3), with the following areas yellow-brown to reddish brown to brownish orange: basal two-thirds of mandible, labrum, clypeus, malar space and short thin stripe ventrally on paraocular area and short thin stripe next to upper inner orbits, ventral surface of antenna (scape usually yellow-brown, pedicel and flagellar segments often pale brown to orange), gena near malar space, pronotal collar, tegula, entire scutellum, middle of metanotum, anterior surface of mesepisternum; legs black with the following orange-brown on coxae, posteriorly on trochanters, femora, tibiae, reddish brown on entire tarsi except hind tarsal segments darker. Forewings clear basally, remainder weakly infusate, more strongly infusate at apical tip beyond closed cells. Metasoma black dorsally and orange brown ventrally, with white-cream patches laterally on T2, T5 and T6.

Pubescence: head with frons glabrous but clypeus and paraocular areas covered with fine, white adpressed hair, inner genal areas with dense cover of erect white hair; antennae with scape and pedicel mostly glabrous but flagellar segments covered with short, erect, unbranched hair; some long, unbranched hairs on axillae; dense area of adpressed, white hair on lower mesepisternum, lateral and vertical surface of propodeum, dorsally on hind coxae, lateral tufts of S3–S5, S6 with apical tip covered with dense brush of short, unbranched, laterally directed hair tufts; propodeal triangle glabrous; mesoventral area between 1st and



Figs 5, 6. *Nomada australensis*: (5) dorsal view of male pygidial plate; (6) outer apical surface of hind tibia of female showing pair of short pegs.

2nd coxae with dense cover of adpressed, white, branched hair; fore coxae with backwardly directed white hair tuft on apical, inner margin.

Sculpture: Frons, vertex and upper paraocular areas with coarse, reticulate-punctate pattern with no spaces between punctures, edges of punctures distinctly raised and not circular but jagged and irregular in shape; lower paraocular areas and malar spaces smooth; clypeus and genae shining and weakly punctate with punctures well separated and edges of punctures smooth and not raised. Mesoscutum and scutellum with coarse, deeply impressed, rounded punctures with edges of punctures not raised, with punctures nearly contiguous to separated by half their diameter; metanotum almost smooth, with several small, well-spaced punctures; propodeal triangle defined by lateral carina, surface weakly striolate mesially and laterally granulose; pronotal lobe and tegula shining and impunctate; T1 shining and almost impunctate, T2–T6 shining but with fine, transverse lineolations.

Female

Body length 5.64–5.89 mm and forewing length 4.24–4.73 mm.

Similar to male but differs as follows (Figs 2, 4): Structure: pedicel not partly enclosed by scape. F2 less than half length of F1, and slightly shorter than F3; remaining flagellar segments subequal, each segment gradually decreasing in length moving apically; F10 nearly twice length of F9. Interantennal area with raised vertical carina between antennal bases, but less prominent and less raised than in male and barely extending onto frons. Hind tibiae at outer apical margin with two straight, ventrally directed and apparently fixed, stout, red-brown coloured, peg-like, apically rounded teeth (Fig. 6). Hind tibial spurs of similar length. Pygidial plate rounded at apex. Colouration: Lower half of face and entire inner eye orbits orange brown; mesoscutum with four, full-length, orange-brown stripes; Pubescence: underturned lateral areas of metasomal terga with hair tufts only on T3 and T4; T5 dorsally with white haired fringe; sterna lacking hair tufts.

Variation. Both sexes are remarkably similar. Males were more variable in size than females.

Adult behaviour (observations by MT)

Milling females of *Homalictus behri* were concentrated within a radius of 30 cm from the nest entrance and 10–80 mm above the pavers. Their numbers varied during the day, beginning about an hour after sunrise, peaking in the late afternoon as females returned to the nest for the night, and dwindling in the hour before sunset.

Through the middle of the day there were perhaps 10 bees at any one time, most of them approaching the nest entrance in a hovering dancing flight. They landed close to the entrance and entered within a second of landing. The female bees generally arrived loaded with pollen.

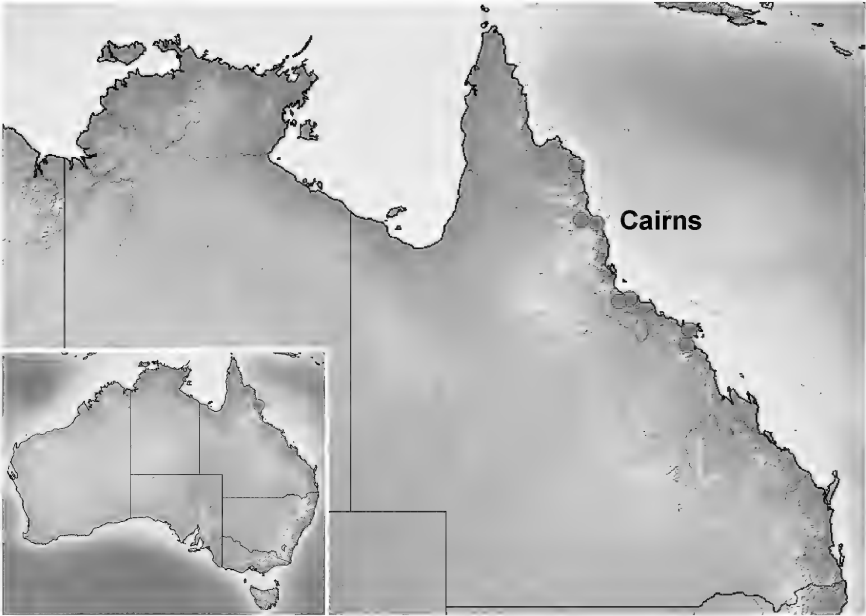


Fig. 7. Map of Australia showing distribution of *Nomada australensis*.

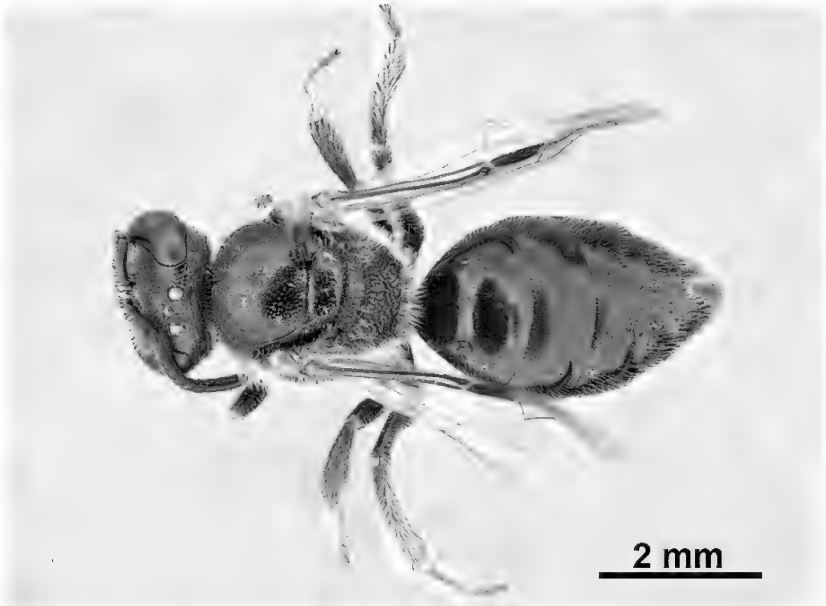


Fig. 8. *Homalictus behri* dorsal habitus.

Adults of *N. australensis* were also observed flying near the *H. behri* nest entrance. They flew more slowly and smoothly than the *H. behri*. Flight was neither random nor straight-line but a wandering path in a consistent general direction once they were within the area being observed. It is possible they were following a scent trail or visual cues.

Adults of *N. australensis* landed and paused at the nest entrance for a few seconds before either taking off again or entering the nest (Figs 9, 10). One *N. australensis* was observed as it landed, waited, aborted attempt at the entrance, took off, landed again and flew off. It was occasionally buffeted by *H. behri* bees entering or leaving the entrance. Interestingly, the *N. australensis* bees collected in the nest exit trap were frequently jostled and buffeted by the *H. behri* bees captured with them as they all crawled around inside the container. No such buffeting was observed between *H. behri* individuals.

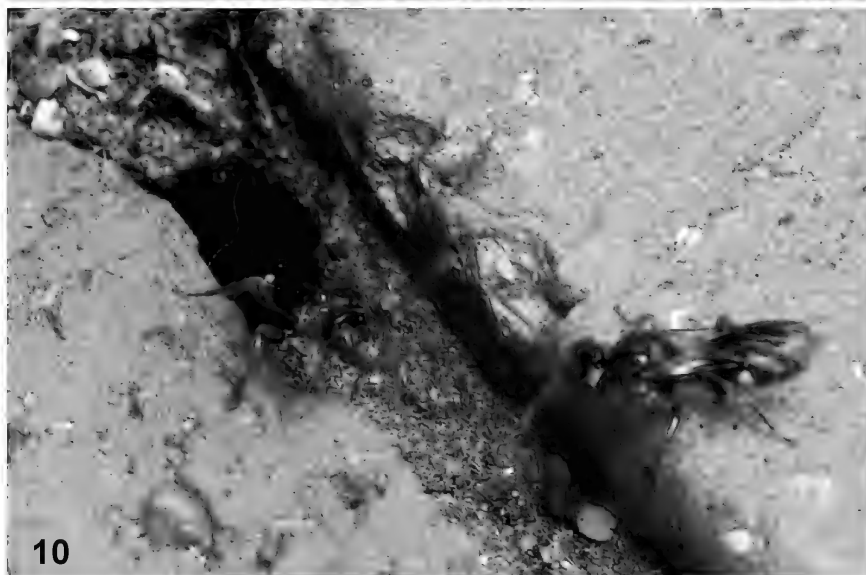
Emerging bees (of both species) always flew off immediately (Fig. 9). Bees emerging from the nest entrances were easily captured in an exit trap (Fig. 11) for collection, examination or release. In November 2019, a single capture trapped about 30 individuals, mainly *H. behri* and a few *N. australensis* bees, in less than an hour. Other captures over shorter time-frames and different times of day collected smaller numbers but over 100 bees were trapped in the period of observation (October 2019 to February 2020) with an approximate ratio of 90% *H. behri* and 10% *N. australensis* bees.

On November 14, 2019, sweep-netting around the nest entrance collected females of *H. behri* and *N. australensis* which flew persistently near the nest entrance. A kleptoparasite and host relationship was strongly indicated on November 26, 2019 when a single *N. australensis* and approximately 20 *H. behri* bees were collected in an exit trap placed over the nest entrance (Fig. 9). Later a *N. australensis* bee was photographed leaving the nest. Unfortunately, excavation of the nest was impractical in the circumstances.

On the morning of December 1, 2019, MT watched as a *N. australensis* bee waited outside the nest for about three minutes. While it was there, a *H. behri* bee emerged, followed by a *N. australensis*. These bees were photographed (Figs 9, 10).

By November 14, 2019, three active nest entrances were apparent, all within 10 cm of each other and by November 25, 2019, there were six. The three newest nest entrances were loosely clustered about 50 cm from the others. The number of nest entrances doubled again in the next two weeks and peaked at 15 nest entrances, all being within a metre of the first. None of the new nests were ever as active as the first few nests. The nature and quantity of loose soil outside new nests suggested these nests were not very deep, perhaps only extending to just below the bottom of the pavers.

On November 14, 2019, an evening survey of MT's garden revealed 10–20 *N. australensis* specimens of both sexes roosting on the seed-heads of *Digitaria*



Figs 9, 10. (9) Female of *Homalictus behri* emerging from host nest entrance and female of *Nomada australensis* waits nearby; (10) Female of *Nomada australensis* emerging from same nest entrance and another nearby.

ciliaris (Retz.) Koeler, summer grass or tropical crabgrass. The *N. australensis* roost was about 10 m from the *H. behri* bee nests and 10–30 cm above ground level. A similar search in January 2020 revealed a group roosting on an unidentified pink-flowering weed, again around 20 cm above ground. Elsewhere in this garden, a few *N. australensis* individuals were found on various occasions on the tips of *Dracaena* Vand. ex L. leaves, up to 1.2 m above ground level. In another garden about one kilometre away, *N. australensis* were seen roosting on twigs of *Leptospermum* J.R.Forst. & G.Forst. (Fig. 10) and *Petrea volubilis* L., about 1.2 m above ground level.

Roosting usually began about 4.30 pm, almost two hours before sunset, and all bees were settled by 7.00 pm. Males and females roosted together. Adults of *N. australensis* sometimes roosted at the tips of their perches, grasping the perch in their mandibles, folding their legs beneath the body and remaining suspended beyond the end of the perch (Fig. 12). Less often, an individual would grasp the perch a small distance from the end and rest along its length. On occasion, two or more bees chose the same perch and were observed to jostle one another as if competing for the preferred position. Males of *Thyreus* Panzer, 1806 and *Lipotriches* Gerstaecker, 1858 were found in the second garden roosting on stems of *Leptospermum* but no roosting males of *H. behri* were encountered in either garden.

Adult flight activity around the nest entrance of *H. behri* was first noticed in mid-October 2019, when (by mid-morning) up to 10 bees would be milling about. This activity declined noticeably by mid-December and, by mid-January 2020, only one or two bees at a time were observed in flight.

With the commencement of the wet season in mid-January 2020, rain flooded the nesting sites and all flight activity of both species ceased. Late in the same month, roosting adults of *N. australensis* were found in the garden just as frequently as in mid-November 2019 and, by late February 2020, at least half as many were observed. Roosting *N. australensis* specimens were seen again on 14 June 2020. Recorded observations by MT and others in other locations in previous years are distributed across almost every calendar month, suggesting some degree of activity of the species throughout the year.

Discussion

MT's observations were consistent with what is known for the genus *Nomada*—i.e. that females wait near the host bee's nest entrance (Figs 7, 8), perhaps waiting for host bees to leave the nest (Cane 1983). Studies on North American *Nomada* found these bees use a range of olfactory cues to detect suitable hosts carrying pollen back into the nest and visual cues to find available nest entrances (Cane 1983; Schindler 2018). Bees of both sexes roost relatively close to the host bee nests and use their mandibles to clamp to the end of twigs (Fig. 12) or elsewhere along the twig if the end position is already occupied. Our taxonomic review of Australian *Nomada* concluded there is only one valid species—*N. australensis*.



Figs 11, 12. (11) Exit trap placed on *Homalictus behri* nest entrance; (12) Male of *Nomada australensis* roosting on dead twig of *Leptospermum*..

Confusion over the taxonomy of the two Australian named *Nomada* species had resulted in incorrect distributions being published. The observations detailed here strongly suggest that *N. australensis* is a kleptoparasite of the halictid bee *Homalictus behri* and that *Nomada* females found at this reported site are presumed to be host species-specific to *H. behri*. Cane (1983) found that while at a generic level, *Nomada* bees have a range of hosts, individual *Nomada* females are usually host specific. The known distribution of *H. behri* is primarily coastal from NE New South Wales into Cape York Peninsula and extends across northern Northern Territory and Western Australia (ALA 2020). The known distribution of *N. australensis* is more restricted being confined to coastal Central and North Queensland (Fig. 7). The robust and heavily punctured integument of the head and mesosoma (Figs 1–4) of both sexes may protect and defend the vulnerable and membranous body parts if the *Nomada* bee is attacked by the communal nesting, larger host female bees (*H. behri* female body length 6–7 mm; Walker 1986, Fig. 8) inside the host's nest. While *H. behri* is the first known host of *N. australensis*, hopefully, this paper will inspire others to seek and provide further host records for the kleptoparasitic genus *Nomada* in Australia.

Acknowledgements

The authors would like to thank Heather Martin, Chris Burwell and Ben Parslow for reading and making valuable comments on drafts of this paper. We are indebted to Juanita Rodriguez for photographing the type of *Neoceratina rubinii* in ANIC and the NHMUK for making available an image of the type of *Nomada australensis*.

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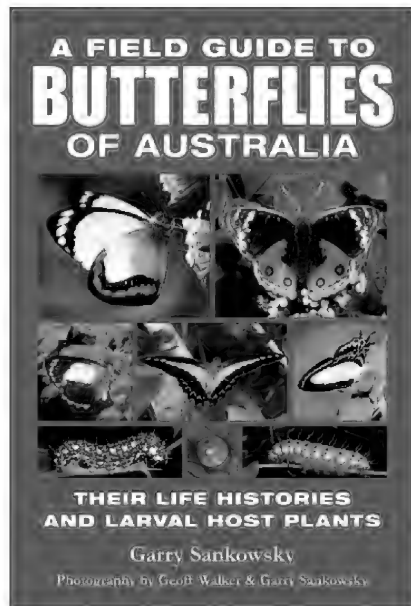
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BOOK REVIEW

A Field Guide to Butterflies of Australia. Their Life Histories and Larval Host Plants by Garry Sankowsky with photography by Geoff Walker and Garry Sankowsky. Reed New Holland Publishers, Sydney, 2020; 400 pp. Price AUS\$45. ISBN 978 1 92554 788 4 (paperback).



Garry Sankowsky has been a household name in the world of Australia's tropical butterflies since the 1970s. Much ahead of his time, he was the first in Australia to open a butterfly house on his property at Long Road, Tamborine Mountain in southern Queensland in the 1970s. In the 1980s he moved to the Atherton Tableland taking up residence at Tolga where he took on the task of revegetating a bare piece of land back to its original state of tropical rainforest. During this growing period, his knowledge of tropical butterflies and more specifically butterfly hostplants also grew exponentially. Thus, in my opinion, his knowledge of Australian tropical rainforest plants, especially butterfly hostplants, is unrivalled, so it seems appropriate that he should try to get even just a small piece of this knowledge collated into book form. Who better to team up with for this project than Geoff Walker from Murrumbidgee in

Melbourne. Geoff has been photographing Australian butterflies now for well over a decade and has come up close and personal to just about all the Australian species. This book offers a great opportunity to finally showcase Geoff's wonderful photos in hard copy format, something that I have long awaited.

Thus, *A Field Guide to Butterflies of Australia* was born. The book illustrates the habitats, distributions, hostplants and adult butterflies of many of the Australian mainland and Tasmanian taxa. The immature stages of many species are also illustrated. Without tediously counting every photograph of butterfly and hostplant in the field guide, suffice it to say, there are thousands of photographs, and these are the strength of the book. The book is an excellent field guide for the amateur who wishes to identify butterflies in the field, and for the more experienced butterfly enthusiast that is searching for that elusive butterfly hostplant and doesn't quite know what plant to look out for, especially in Australia's tropics. In addition, the lists of hostplants and the sections on the most suitable species of hostplant for the garden are very useful. The book is a soft cover but with a robust plastic sleeve, which makes the book a suitable guide to be taken into the field. What I found particularly useful were the photos of the hostplants of the Danainae which are of special interest to me. In addition, the section on suitable species of *Aristolochia* to grow in one's garden is very impressive and useful, especially so if you live in the parts of the country where

birdwings, greasys and red bodied swallowtails occur. The photographs depicting the adult butterflies and immature stages of *Hypochrysops* were particularly beautiful and stunning.

While the book excels in hostplant information and beautiful butterfly immature and adult photographs, it unfortunately falls short in its consistency and its accuracy in butterfly distribution maps, up-to-date butterfly taxonomy, and it contains a run of spelling errors and mistakes. It seems that much emphasis has been placed on getting the photographs right, but this regrettably has been at the expense of the text.

A map of the known distribution is provided for each species. For some species, its distribution is stated, others not. The current distribution of *Anthene lycaenoides* has extended south to Brisbane since at least 2015 (not around Mackay as the distribution map shows), while the map for *Junonia hedonia zelima* shows it extending into northern New South Wales but it was extirpated from southern Queensland at least 40 years ago. For some reason the two Satyrines, *Elymnias agondas* and *Taenaris artemis* are on pages 141 and 142 while the rest of the Satyrines are on pages 171–191. Occurrences in Torres Strait are very inconsistent. A few examples: some species are correctly identified as occurring on the Torres Strait islands (e.g. *Bindahara phocides*), while others that also occur on the islands are not indicated as such (e.g. *Deudorix diovis*), while some are incorrectly stated as occurring on the islands (e.g. *D. epijarbas*). The authors inappropriately designate the common name of *Yoma algina netonia* as the Iron Range Lurcher and illustrate its distribution as centering around Iron Range, when it has been recorded along the whole east coast of Cape York Peninsula from Somerset at Cape York to Peach Creek, 25 km NNE of Coen (2016). Perhaps Ocellated Lurcher would be a more appropriate common name. In addition, for some reason *Y. sabina* and *Y. algina* and others (which only occur as one subspecies in Australia) are indicated atypically to subspecies level.

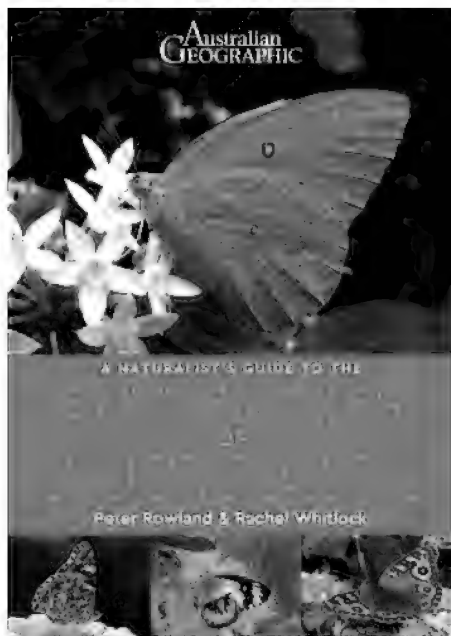
Some taxonomic changes published since Michael Braby's field guide have not been updated in the book. Some examples are: *Danaus petilia* was listed correctly on page 115, but on page 116 was listed as *D. chrysippus* (with both names listed in the index), *Y. sabina parva* is now *Y. sabina sabina*, *Philiris nitens lucina* is now *P. lucina*, *Pseudalmenus chlorinda barringtonensis* is now *Ps. barringtonensis*, the southern mainland population of *Neolucia hobartensis* is now *N. h. albolineata*. In addition, several spelling mistakes are disappointing: *Euschemon rafflesia* (as *rafflesia*) pages 201, 202, *Acrodipsas cuprea* (as *cuphrea*) page 274, darts on page 257 is spelt Dartss, and Charaxinae on pages 138–140 is spelt Charraxinae. Finally, there are some simple mistakes, *Delias ennia ennia* should be *D. e. tindalii*, *Zizina hylax* should be *Zizula hylax*, the image for *Tisiphone abeona rawnsleyi* is missing and in the Acknowledgements page, Ross Kendall is spelt Ross Kendal, to name a few.

While the text issues with the book are annoying, this is more than made up for by the quality and informative nature of the photographs. At \$45 the book is certainly a good buy when you consider the depth of hostplant information and the quality of the photography. Adding up the years of expertise lying in these pages, I think that the book is a good addition to the bookcases of butterfly amateurs, collectors and professionals.

Reviewed by Trevor A. Lambkin

BOOK REVIEW

A Naturalist's Guide to the Butterflies of Australia. Peter Rowland and Rachel Whitlock. John Beaufoy Publishing Limited in association with Australian Geographic, Oxford, England. 2020. 176 pp; paperback, 128 mm x 180 mm; ISBN 978-1-912081-45-5. Price A\$24.99.



Australia has a rich tradition of producing high quality, authoritative field guides on all aspects of natural history. Butterflies are no exception. The early publications by G.A. Waterhouse's *What Butterfly is That?* (Waterhouse 1932), I.F.B. Common's *Australian Butterflies* (Common 1964) and I.F.B. Common and D.F. Waterhouse's *Butterflies of Australia Field Edition* (Common and Waterhouse 1982) were benchmark publications, setting high standards of accuracy, reliability and presentation, making complex scientific information accessible in a format that was clear and concise for the layperson. These works set the foundation for modern authoritative guides on Australian butterflies that followed (Braby 2004, 2016). In recent years

there has been a plethora of guides devoted to Australian butterflies (e.g. Orr and Kitching 2010, Field 2013, Sankowsky 2015, 2020, Bond 2016), highlighting the burgeoning interest and popularity of this group of insects. I was therefore intrigued by the release of yet another field guide on Australian butterflies, this one by the Australian Geographic series on Australian wildlife. Unfortunately, my expectations of high standards of scholarship were not met, which will become apparent in this review.

At first glance the book has a nice feel—it is small and compact, light and printed on good quality paper. Thus, it fits snugly into ones back-pack or glove box of the car. The front matter is minimal and deals with the origin of butterflies, their roles as pollinators (and pests), life cycle, and a glossary. Unfortunately, it is not clear who is the target audience: the purpose and intended readership are not stated. The illustrations are generally clear and easy to follow, although I was not able to find the egg of *Papilio aegaeus* (p. 8) and, for the larva of the same species (p. 9), the mandible, thoracic legs and abdominal prolegs and anal clasper are completely hidden from view despite indicator lines purporting to show these structures. Then follows the species accounts, which make up the bulk

of the book, with half a page devoted to each species. For each species there is a header for the common name, followed by the scientific name, size (wingspan) and alternative common name(s). The text includes information on description, distribution, habitat and habits, and is easy to read with minimal scientific jargon. One or sometimes two pictures are provided of a living butterfly of each species. These pictures are generally of high quality, although there are issues (see below).

The end matter includes a checklist of the Australian fauna (extracted from the Australian Faunal Directory, which I manage on behalf of the Australian Biological Resources Study), so the nomenclature is up-to-date until that point (as of 5 August 2019). However, *Arhopala centaurus*, a species which does not occur in Australia, is listed and is incorrectly ascribed to *Arhopala eupolis* which is illustrated on p. 125. Common names generally follow modern treatments, except the well-known Common Brown for *Heteronympha merope* is dubbed the ‘Western Brown’, which is reserved for the subspecies *H. merope duboulayi* in Western Australia. *Taractrocera dolon* is called the ‘Sandy Grass-dart’ instead of River-sand Grass-dart, and *Ogyris halmaturia* is now ‘Waterhouse’s Azure’ instead of Eastern Bronze Azure. The arrangement of families does not follow recent internationally accepted phylogenetic hypotheses of family-level relationships (e.g. Regier *et al.* 2009, Mutanen *et al.* 2010, van Nieukerken *et al.* 2011, Simonsen *et al.* 2012) so, for example, the Pieridae and Nymphalidae are listed before the Hesperiidae. The checklist also includes the broad occurrence of each species at the level of state/territory, although separate entries are given for the Torres Strait Islands and, presumably, Christmas Island (given as CI, but the acronym is not listed as such in the distribution key on p. 10).

The book concludes with a list of useful websites, some miscellaneous references, acknowledgements, and an index to both common and scientific names. The absence of several major natural history clubs and societies from the list of websites, such as the Butterflies and Other Invertebrates Club (in Qld), Entomological Society of Victoria (in Vic.), Butterfly Conservation South Australia (in SA), and Western Australian Insect Study Society (in WA) is a major omission.

The book states that “Great care has been taken to maintain the accuracy of the information contained in this work”. However, this statement must be seriously challenged. The cornerstone of any publication is accuracy of information, especially with respect to identification of species. Perhaps my deepest concern with this publication is the exceptionally high number of errors in species level determinations. The illustrations of at least 32 species have been incorrectly identified (Table 1). Of particular concern is the representation of three species (*Pieris brassicae*, *Graphium antiphates*, and *G. agetes*) that do not even occur in Australia. The inclusion of such species is not only misleading but embarrassing. The purpose of regional field guides is to assist people, especially beginners, in identifying the components of our natural world for the regions for which they are intended. In addition, species level identification is not provided for five taxa.

Table 1. List of illustrated, misidentified species followed by their correct identifications.

Pieris rapae (left image) is *Pieris brassicae* (p. 5).
Graphium aristeus is *Graphium antiphates* (p. 12).
Protographium leosthenes is *Graphium agetes* (p. 15).
Papilio demoleus sthenelus (left image) is *Papilio demoleus malayanus* (p. 19).
Ornithoptera priamus (both images) is *Ornithoptera euphorion* (p. 17).
Eurema alitha is *Eurema hecabe* (p. 23).
Delias argenthona is *Delias mysis* (p. 32).
Danaus chrysippus (both images) is *Danaus petilia* (p. 36).
Danaus genutia (right image) is *Danaus petilia* (p. 36).
Anisynta tillyardi is *Toxidia parvula* (p. 79).
Hesperilla crypsigramma is *Toxidia peron* (p. 83).
Hesperilla sexguttata is *Pelopidas lyelli* (p. 87).
Neohesperilla senta is *Pelopidas lyelli* (p. 90).
Proeidosia polysema is *Pelopidas* sp. (p. 92).
Signeta tymbophora is *Toxidia peron* (p. 93).
Toxidia andersoni is *Toxidia doubledayi* (p. 93).
Trapezites luteus is *Trapezites eliena* (p. 99).
Trapezites phigalioides is *Trapezites iacchoides* (p. 100).
Arrhenes dschilus is *Ocybadistes ardea* (p. 104).
Ocybadistes walkeri is *Suniana sunias* (p. 107).
Taractrocera anisomorpha is *Suniana* sp. or *Ocybadistes* sp. (p. 110).
Taractrocera dolon is *Suniana sunias* (p. 110).
Taractrocera ilia is *Ocybadistes flavovittatus* (p. 111).
Telicota anisodesma is *Cephrenes augiades* (p. 113).
Philiris spp. is *Eirmocides absimilis* (formerly *Candalides*) (p. 124).
Pseudodipsas cephenes is *Anthene lycaenoides* (p. 125).
Arhopala madytus (right image) is *Arhopala* sp. (possibly *eupolis*) (p. 126).
Jalmenus daemeli is *Jalmenus* sp. (*ictinus* or *pseudictinus*) (p. 129).
Candalides consimilis is *Eirmocides margarita* (formerly *Candalides*) (p. 136).
Candalides margarita is *Eirmocides absimilis* (formerly *Candalides*) (p. 139).
Psychonotis caelius is *Nacaduba cyanea* (p. 152).
Theclinesstes miskini is *Catopyrops florinda* (p. 153).

I was puzzled as to why the names were not given, but close examination of the illustrations of these species indicated they could be readily identified, as follows: *Pantoporia* spp. is *Pantoporia consimilis* (p. 47); *Yoma* spp. is *Yoma algina* (p. 54); *Deudorix* spp. is *Deudorix diovis* (p. 134); *Nesolycaena* spp. is *Candalides urumelia* (formerly *Nesolycaena*) (p. 140); and *Jamides* spp. is *Jamides phaseli* (p. 145).

A stated aim of the book is “An easy to-use identification guide to 301 [actually 281 species] butterflies covering the species most commonly seen in Australia.” However, eight species covered in the species descriptions are not established on the Australian mainland, but are either rare vagrants (*Danaus chrysippus*, *Euploea climena*, *Hypolimnas anomala*, *Junonia erigone*) or restricted to remote islands such as Christmas Island or the Torres Strait Islands (*Appias olferna*, *Euploea leucostictos*, *Taenaris catops*) or establish only temporarily (*Vanessa cardui*). Thus, their inclusion in the book is unwarranted because the average person is unlikely to ever observe them. Moreover, the photographs of 14 species are too poor or there is not enough diagnostic information in the image to be useful for identification purposes (and that’s assuming the purported species names provided are correct in the first place), viz: *Hypocysta pseudirius* (p. 67), *Hesperilla malindeva* (p. 85), *Hesperilla mastersi* (p. 85), *Neohesperilla crocea* (p. 89), *Parnara amalia* (p. 103), *Taractrocera ina* (p. 111), *Telicota ancilla* (p. 112), *Telicota augias* (p. 113), *Telicota mesoptis* (p. 115), *Ogyris amaryllis* (p. 127), *Catochrysops panormus* (p. 142), *Neolucia mathewi* (p. 150), *Theclinesthes onycha* (p. 154), and *Zizula hylax* (p. 156). The image of *Pseudalmenus chlorinda* (p. 132) shows an adult in which the wings are either deformed or not fully expanded (i.e. the butterfly has just eclosed from its pupa) and thus does not represent this spectacular species at all well.

In addition, some information in the text is quite misleading. For example, it is claimed (pp. 4, 5) that the butterflies evolved 200 million years ago and fed on gymnosperms, before the rise of the angiosperms, but this contradicts our modern understanding that the butterflies arose in the Late Cretaceous followed by a period of major diversification after the K-Pg mass extinction event (i.e. well after the radiation of flowering plants) (Wahlberg 2006, Wahlberg *et al.* 2009, Heikkilä *et al.* 2012, Espeland *et al.* 2018). The text for the Tawny Coster *Acraea terpsicore* says “Adults undertake mass migrations, which has aided the expansion of its range from India and Sri Lanka through South-east Asia towards Australia”, which is complete nonsense. The butterfly first appeared in Thailand (Chiang Mai) in April 1984 and took 28 years to slowly spread through the Malay Peninsula, Greater and Lesser Sunda Islands before it reached Australia (Darwin) in April 2012 (a distance of 6,000 km) (Braby *et al.* 2014), hardly evidence of mass migration from India. Only recently has there been evidence of migration at the leading edge of the expansion front in Queensland (Chowdhury *et al.* 2021).

We live in an era in which information is both voluminous and accessible, largely due to the internet. The challenge for publishers is to moderate that information, to disentangle fact from fiction, and to have their works critically peer reviewed by experts. Neither of these steps appear to have been followed in this case. Sourcing images from the internet without checking their identification, such as through the iNaturalist vetting system or through Butterflies Australia database moderation process (Sanderson *et al.* in prep.), is clearly not acceptable. I believe there remains scope for a competent field guide on Australian butterflies portraying images of live adults, or a book combining both live and dead (museum) specimens to aid

in identification. There are many good examples overseas (e.g. Glassberg 1999, Tolman 2001, Lo 2005, Khoon 2010, van der Poorten and van der Poorten 2018) of how such field guides can be done to a high level without compromising the amount of text or size of the book.

Reviewed by Michael F. Braby

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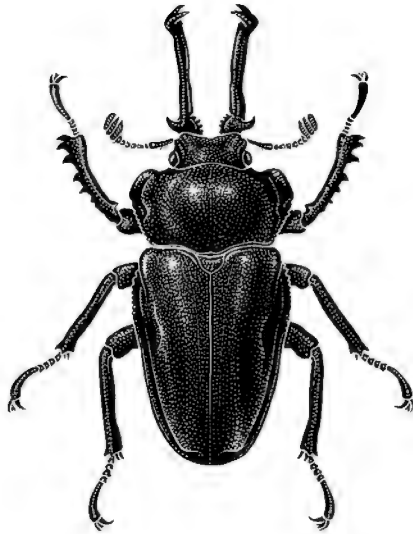
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